VEINS OF THE BRAIN.

BROWNING.

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THE VEINS OF THE BRAIN AND ITS ENVELOPES.

Their Anatomy and Bearing on the Intra-cranial Circulation.

By WILLIAM BROWNING, M. D.,

BROOKLYN, N. Y.

BROOKLYN, N. Y.
F. B. O'CONNOR, JR.,
68 AND 70 COURT STREET.

1884.

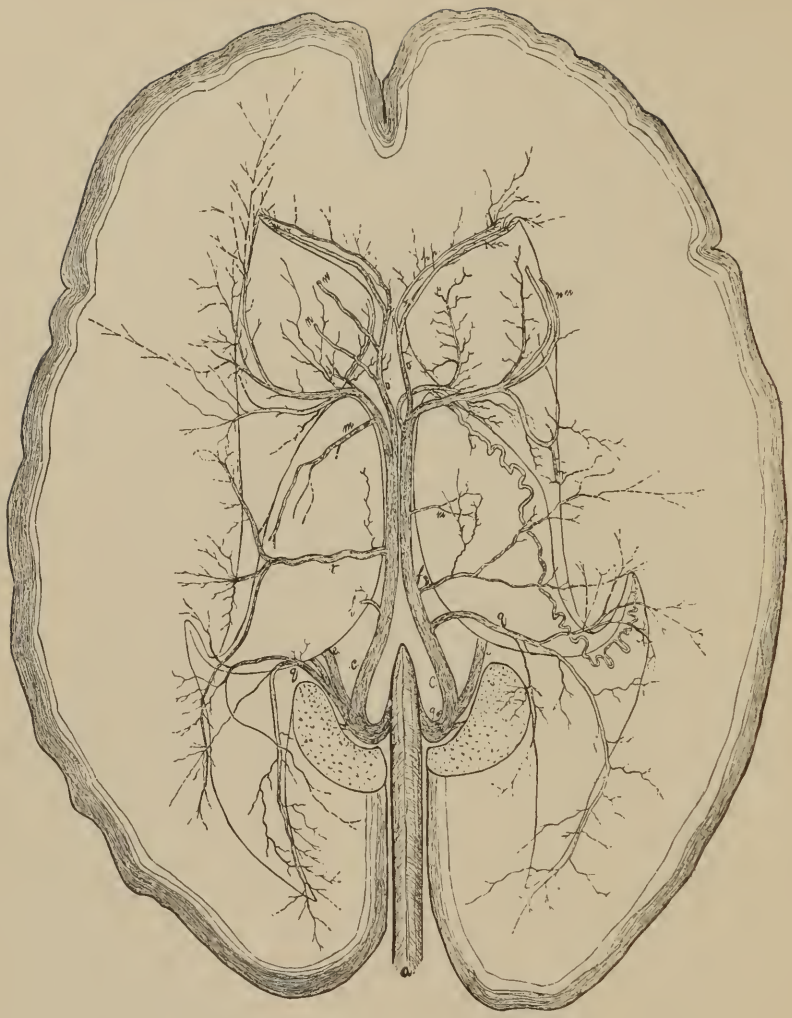

FIG. 1. THE INTERIOR OR VENTRICULAR VEINS (*seen from above*).

The ventricles are laid open as completely as possible, the splenium, fornix, etc., having been cut away. The corpus striatum, thalamus opticus, anterior and posterior horns, are represented in outline, but not shaded. The discharge into the straight sinus was copied from a corrosion preparation. The vena Galeni is hidden under the straight sinus. It is, of course, understood that the vein branches are not all on the same level, although this cannot readily be shown in the drawing.

a, Sinus rectus; *c*, Portio curvata of internal vein; *e*, Vena basilaris Rosenthali; *f*, Vena corporis callosi posterior interna; *g*, End of v, corporis callosi posterior externa; *l*, Vena choroidea (not represented on the left side); *m*, Vena thal. optic. profunda; *n*, *n*, Venæ medullares superiores; *o*, Vena anterior ventriculi; *p*, *p*, Venæ cornu anterioris; *q*, Vena cornu posterioris; *r*, Vena lateralis directa.

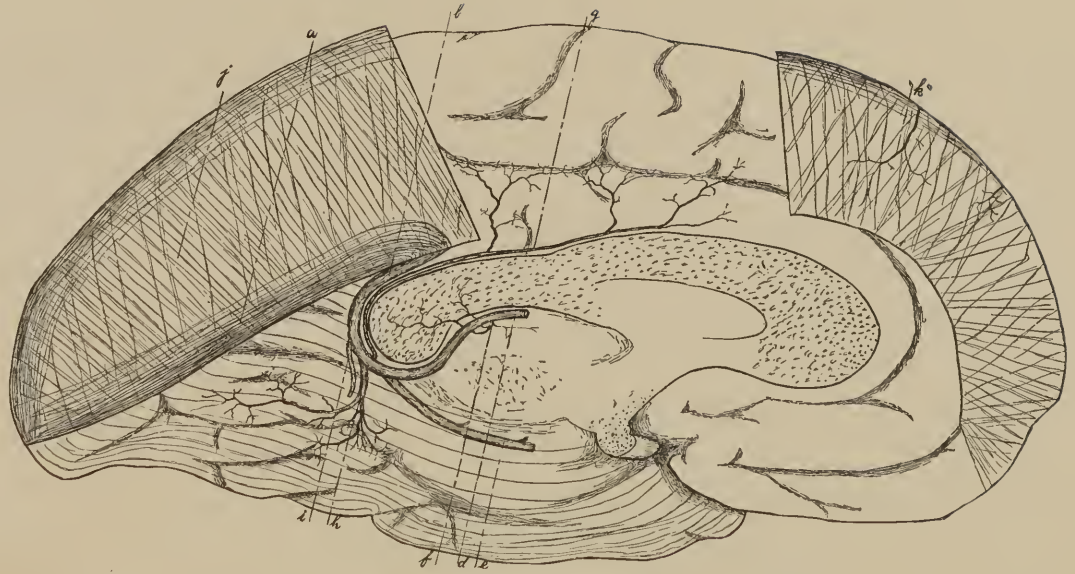

FIG. 2. VENÆ MAGNA GALENI (*the longitudinal fissure, seen from the side*).

a, Sinus rectus ; *b*, Vena Galeni ; *d*, Portio recta of the internal vein ; *e*, Vena basilaris ; *f*, Vena corp. callos. post. interna ; *g*, Vena corp. callos. post. externa ; *h*, Vena occipitalis interna ; *i*, Vena cerebelli superior ; *j*, Falx cerebri ; *k*, A vein in the falx. Both illustrations are three-fourths of the natural size.

VEINS OF THE BRAIN.

INTRODUCTORY.[1]

SINCE the publication of Breschet's great work on the veins of the human body (Paris, 1824), but little had been done in this field until Braune began his investigations. Some years ago he undertook an atlas of the veins of the human body, but it remains as yet incomplete. The anatomical portion of the present monograph was prepared for the most part at Prof. Braune's laboratory in Leipsic, and I take pleasure in acknowledging that whatever value it may possess is largely due to his very kind interest and aid.

The anatomy of the cerebral veins has been even more neglected than that of the other veins of the body. It seemed, therefore, desirable to fill out certain deficiencies in this respect.

1. To examine anew the veins of the surface of the brain in their arrangement, anastomoses and efferent courses.

2. To determine the sources of the vena magna Galeni in the ventricles of the brain.

3. To describe the courses of the veins in the fissure of Bischat (transverse fissure of the brain).

[1] The first sixteen pages of this monograph appeared in the January number, 1884, of the *Annals of Anatomy and Surgery*, a journal which has since suspended.

4. To systematize and classify the whole subject as far as possible.

It may seem as though the veins are described in the following pages with too much fineness, beyond the point where irregularities cease to be systematizable. Such criticism will only hold, however, when it is shown that the descriptions, based as they are on actual preparations, do not hold good when compared with a much larger number of cases. Fair descriptions of the sinuses of the dura mater may be found in the various anatomical text-books, and more complete ones in the articles of Knott and Trolard, so that only their relations to the veins need be included in the present plan.

LITERATURE.

With the exception of the text-books, scarcely anything has appeared about the inner cerebral veins since Rosenthal's paper, "*De Intimis Cerebri Venis*," in vol. 12 of the *Acta Leopold. Carol.* Bonn, 1824.

But little new matter further presents itself concerning the superficial cerebral veins. Trolard's article, "*Recherches sur l'Anatomie du systeme veineux du crane et de l'encephale*" (*Arch. gen. de Med.*, 1870, vol. i.), contains some things of interest in this connection. It presents also a description of all the blood sinuses in the skull.

In the Transactions (vol. i.) of the London International Medical Congress, is a description, by Knott of Dublin, of the cerebral venous sinuses, their variations, etc., based on the examination of forty-four skulls. The numerical ratio in which each of the different forms and variations were found is its chief feature.

Rüdinger (*Beitrag zur Anatomie des Gehörorgans, der venösen Blutbahnen der Schädelhöhle*, etc., Munich, 1877,) has called special attention to certain anatomical relations of the sinuses.

A detailed description of the distribution and structure of the finer vessels in the district treated of is to be found in the monograph of Langer (*Ueber die Blutgefässe der Knochen des Schädels und der harten Hirnhaut ;* Vienna, 1877).

Heubner's studies on the arteries of the brain (*Luetische Erkrankungen des Gehirns*, etc., Leipsic, 1874), as also Duret's article (*Recherches anatomiques sur la circulation de l'encephale. Arch. de Physiolg.*, 1874, No. 6), have once more shown the importance of the peculiarities of the brain vessels in the cerebral circulation.

TECHNIQUE.

The examinations, upon which the following description is based, were made on a variety of preparations—on fresh and on hardened brains, on those from adults,[1] children and animals. Six adult brains were examined very thoroughly, five others somewhat less so. Besides these, a much larger number were partially examined to determine certain questionable relations. There were also included half a dozen infantile and fœtal brains, besides those of several species of animals.

It is very difficult to thus examine a brain in all its parts, and yet it is very important that this be done so far as possible, since otherwise the variations, which occur in nearly every brain, cannot be understood.

Various materials were employed in injecting. The sinuses and their adnexa[2] can best be studied from corrosion preparations. For the examination of the finer and finest veins the Berlin-blue solution adapts itself very well, but to make more lasting preparations, not only of the larger but

[1] These were from suicides, and for the most part free from diseased conditions.

[2] By this are meant the areolar spaces along the various sinuses (*lacunæ laterales sinus*) and the terminations of the veins in the sinuses. Especially for the correct determination of the angle made by veins on emptying into the sinuses, is the corrosion material the surest means.

still more of the finest veins, the new paste material[1] of Pansch of Rostock for cold injections has proven by far the best of anything. This in its simplest form is readily prepared. Starch and cold water in about equal parts are thoroughly stirred together, some coloring matter—*e. g.*, cinnabar, if red be desired—is added, and then a small quantity of alcohol, which suffices to make the whole very fluid. On injecting this the spirit rapidly diffuses into the tissues, and in a few seconds the whole is firm. It is advisable to employ a syringe large enough at one filling to inject all the vessels it is intended to examine. It is also necessary after once beginning an injection with this material to work expeditiously. It can then with comparative ease be thrown—*e. g.*, from the aorta into the tips of the fingers and toes. It hardens almost too soon—in the finer vessels in a few seconds. Whether such preparations can be preserved a long time in alcohol without spoiling the injections, I am unable to say, though it is claimed they can be. For a short time there is no trouble.

The natural blood-injection[2] may also be made use of in many cases where the brain is comparatively fresh, for the examination of the smallest vessels, especially in the medullary substance. One must then start from a vein-trunk and follow out its branches, to avoid the possible mistaking of an artery for a vein.

Berlin-blue injections must be examined soon, to get safe

[1] Wikseminski (*Arch. für Anat. und Physiolg.*, 1880, p. 232) has suggested the following modification: Flour, 3 parts by weight; cinnabar, 1 part by weight; glycerine, 15 parts by weight; carbolic acid, 2 parts by weight; water, 30-40 parts by weight. The flour and cinnabar to be rubbed together dry, then add glycerine, and then the carbolic acid dissolved in some alcohol. Other modifications have also been proposed.

[2] It is not unusual to find gas in these vessels, of about the same composition, doubtless, as that which can be exhausted from venous blood. Gendrin (in his translation of Abercrombie, p. 310) refers to this same fact, and adds a case of Morgagni's, where cerebral arteries, veins and sinuses contained no blood, but were filled with air. This is one reason why a really hyperæmic brain may not appear so at the autopsy.

results. On leaving them some time in spirit, other tissues take up the color. Pansch's material is quite free from this; it can be examined immediately or at one's leisure, and, moreover, if it gets on the tissues outside of the vessels, it can be readily washed off with a stream of water.[1]

To make good and continuous injections of these vessels is something of a task. Even with the arteries, special methods of procedure are found necessary. How much more difficult this is with the veins may be imagined from the thinness of their walls and consequent tendency to collapse or to rupture; besides it is very difficult to introduce a canula into the finer veins. And these are not the only draw-backs. There is trouble for instance in attempting to inject from the jugular vein, the injecting mass rarely flowing beyond the sinus, at the most but 1-3-4 cm. into some of the larger veins.

This remained the case even after removal of the skull-cap, except where the material had oozed from the many small openings, in the vicinity of the long sinus; these were simply the connection with the diploë veins as described by Langer and others.

Nor did the material press into Galen's system farther than the posterior end of the thalami optici. One is compelled here as well as in certain of the cerebral arteries to inject piece-meal. It is relatively easier in young and fœtal brains since in them the pia does not sink as deeply into the sulci of the surface.

Any other special methods employed will be described as they occur.

The cerebral veins like those of other parts of the body present many variations. Those of most constant occur-

[1] Since writing this I find that Kollman of Basel had just previously recommended Pansch's material as being admirably adapted for injecting cerebral veins.

rence will of course be described first and thereafter those which must be considered as variations.

PRESENT KNOWLEDGE OF THE SUBJECT.

The venous passages of the brain and cranial cavity may be divided into two classes.

1. Into the rigid walled sinuses, which are protected against compression by the firm inclosing dura mater, and constitute therefore canals which are always open, and into which the soft collapsing veins of the brain surface and interior empty.

It should be remarked here (*a*), that according to the investigations of Rüdinger (*l. c.*, p. 5), a confluens sinuum, in the sense of the old writers, does not exist; (*b*), moreover that the foramen jugulare is very much affected in its size and form by the numerous emissaries of varying caliber; (*c*), that according to Langer, valves may occur at the orifices of the diploë-veins; (*d*), that the vena ophthalmica may by an increase of pressure constitute an efferent canal of the sinus cavernosus; (*e*), that there is a vena facialis anterior, which on occasion conducts thrombosis from the surface of the face to the brain sinuses, and lastly (*f*) that the sinus cavernosus represents a colossal perivascular structure about the carotid, in a way similar to that established for certain lymphatics accompanying veins.

2. Into the veins of the brain proper. Here again the veins of the dura are quite separate from those of the pia, and of the brain substance itself. The knowledge of the latter is especially defective and non-exact. Many apparent contradictions and obscure statements depend upon variations in the occurrence and size of certain veins, or upon one writer's having overlooked the results and nomenclature of other observers.

Of the many connections between the veins on the surface of the brain, only one is specially mentioned, the so-called *anastomotica magna* (*vena anastomotica magna cerebri*, or Trolard's *la grande veine anastomotique*).

No one has heretofore so much as attempted to define or indicate the limits of the various vein-districts. Rosenthal himself followed the internal cerebral veins only as far as the walls of the ventricles, and even that far incompletely, and not always correctly. The veins of the posterior horn, of the lateral horn and of the medullary substance in general have been as good as ignored. No attention has been given heretofore to the effect upon the cerebral circulation of the peculiarities in course and termination of the veins.

ANATOMY IN DETAIL.

These veins can be divided into three classes (strata), according to their relation to one another when the body is standing upright. Such a division is but general, and not closely exact, since they communicate pretty freely with and often substitute one another. Accordingly there are:

I. Upper Layer. Venæ cerebrales superiores and others, which empty into the sinus longitudinalis.

II. Middle Class. Galen's system, or the venæ cerebri internæ, which discharge into the sinus rectus.

III. Lower Stratum. Venæ cerebrales inferiores. Such veins as end in the sinuses at the base of the brain.

I. The veins which terminate in the sinus longitudinalis:

These are threefold:

a. Venæ cerebrales superiores, the largest.

b. Vv. duræ matris cerebri, though only in part.

c. Emissaria Santorini, together with veinlets from the diploë.

Ia. The superior veins return the blood from the upper

cerebral surface, and also from a part of the opposed surfaces of the hemispheres in the longitudinal fissure.

Some of the depressions or furrows on the inner surface of the posterior superior portion of the parietal bone are said (Pozzi) to be caused by these superior veins. The sulcus centralis is also, according to Krause (*Virch. Arch.*, 1881, p. 227), occupied by a vein which is much more developed in the fœtus than in the adult.

The finest vein-branchlets arise everywhere in the sulci and on the exposed surface of the convolutions, whence the vein trunks run directly across to the sinus. They seem to make but little attempt at accommodating themselves to the course of the convolutions or of the depressions between them. Many combine, while still in the sulci, to form considerable vessels, others forming on the crest of the gyri. The finest veinlets are richly distributed everywhere, as will be more fully described in speaking of the communications between the various veins.

Veins of second grade (as to size) sometimes pass under a neighboring vein-trunk before reaching their own. In their arrangement with respect to the sinus, these vessels show certain peculiarities. They may very properly be divided, as has indeed been unconsciously done by others, into anterior superior veins, discharging into the front third of the sinus; and into posterior superior veins, discharging into the posterior two-thirds of the sinus. Between these there is often a distance of 4-5 cm. where no vein discharges.

This appearance was most noticeable on fœtal brains. The anterior ones are in general much smaller than those about midway, and the most posterior ones likewise diminish somewhat in size. It is asserted by Henle (Anat.) that these veins gradually increase in size from the front backwards; but, as just described, this as a rule will not be found true for the most posterior ones. Where the brain is broadest these veins will be largest—*i. e.*, approximately in

the middle. The sinus longitudinalis, in the latter part of its course, also receives no veins.

These superior cerebral veins often combine shortly before their termination to large trunks, so that only 6-8 are then to be seen; or, on the other hand, 12-15 may be found, both large and small. The two sides do not always present the same number; sometimes there are more on the right, sometimes more on the left. Yet, despite their variable number, it is possible to demonstrate a paired arrangement of these veins. This holds especially for the posterior superior veins. (See above anterior and posterior.) The anterior ones often show the same, but they are smaller and more irregular in number and arrangement. The posterior veins on either side empty into the sinus directly opposite those of the other side—*i. e.*, symmetrically as pairs.[1]

The last pair ends in the sinus, as above indicated, from 3-5 cm. before the torcular Herophili at about the point where the sinus begins more rapidly to descend. The second or third pair from the last may be somewhat stronger developed, and then probably represents the so-called vena anastomotica magna.

Besides this paired arrangement of the superior cerebral veins, I have also found each of them in fœtal subjects to be double. In adults the same is true, but in a less marked degree. These two veins or vein-branches are generally of unequal size, the larger one coming from the convexity, the other lying behind and internally to the first, and arising to a large extent on the opposed surface of the great longitudinal fissure. The two branches come together at about the juncture of convexity and fissure. They may soon unite to one trunk, but generally in their further course to the sinus

[1] This and what follows reminds one of the law of distance between vein-valves and vein-branches and their being originally double, recently formulated by K. Bardeleben. (*Jena. Zeit. für Naturwiss.* 1880, xiv. Abstract in *Med. Centbl.*, No. 10, 1881.)

they lie close beside each other within a common sheath, and appear as one trunk, without, however, losing their integrity as independent vessels. The vena Galeni sometimes shows an analogous partition. No artery lies between these double veins (cf., however, below). Sometimes this double arrangement of the veins is very pronounced. In other cases only when each is followed independently to the sinus does it become evident that many of the veins empty into the sinus by twos, and that many others are made up by two uniting just as they perforate the sinus wall. Almost always some of the paired, as well as their constituent double veins, are wanting to complete the diagram. Such deficiencies are made good by the increased size of the other vessels of the respective side.

It was long since observed that the more anterior venæ cerebrales superiores take a course very nearly at right angles[1] to the sinus, and that the posterior ones take more and more an oblique course, to such an extent that the most posterior ones must run forward a distance of 3-4 cm. Here they terminate in the sinus with a very acute angle, against the blood-current. The vein coming from the brain-surface makes at the edge of the longitudinal fissure, or somewhat further out and back in the pia, the necessary angle in order to approach the sinus as described. It then runs a short distance forward before leaving the pia.

A matter to which I have elsewhere (Am. Journal of Med. Sci., Sept., 1882, p. 379,) called attention is the relation of the point where they leave the pia to the point where they empty into the sinus. The anterior veins, more often than the posterior ones, spring over from the pia

[1] According to Quain-Hoffman (*Anatomie*), "mostly a short distance from front backwards along the sinus and then discharge into it," which is true for many cases.

to the dura at some distance, 1-3-4 cm., laterally from the sinus. The posterior ones reach the side of the sinus, and the most posterior ones even curve forward before leaving the pia, but the distance from this point to that where they empty into the sinus is at least equal to that in the varying anterior veins. These relations may more often be noticed in the adult. In the fœtus the posterior veins seem to present free tubes for some distance after leaving the pia and before penetrating the dura. This free piece of vein is very short or wanting in the anterior veins, but increases materially in the posterior ones. In the adult subject, this latter condition is apt to be obscured by Pacchionian granulations, and adhesions between dura and pia mater. This is not entirely anomalous. According to Key and Retzius (*Studien*, etc., Stockholm, 1875, I. *Hälfte*, p. 134), a not inconsiderable number of vessels in the subarachnoidal spaces run for long distances quite free, enclosed in sheaths of endothelial cells.

Another peculiarity is to be noted in this connection. The anterior veins empty above or at the side of the sinus, comparatively unhindered, as though they came straight from the dura mater. The veins further back, however, discharge more and more at the side and bottom of the sinus, and those farthest back empty almost without exception at the bottom. Many of the latter, indeed, must take an upward course through the falx cerebri and traverse a considerable distance before they reach the lowest part of the sinus.[1]

Moreover these posterior veins do not open as freely into the sinus as those farther forward. Their course through Pacchionian granulations, parasinoid-

[1] Trolard (*l. c.*, p. 260,) came partly to the same conclusion. "*Ces derniers s'ouvrent dans l'angle inferieur du sinus. Les autres s'ouvrent sur les parties laterales.*"

al [1] spaces, and the firmer parts of the sinus wall make them seem like tortuous passages and pockets in the parietes of the long sinus.

The termination of the posterior superior cerebral veins in an acute angle in the walls of the sinus forms a valvular arrangement, preventing pretty completely any reflux of blood from the sinus into these veins. Horner (Anat. and Histl. Phila., 1851), says that the superior cerebral veins are supplied with valves, which hinder the regurgitation of blood from the sinus longitudinalis. Luschka (*Anat. d. Kopfes*, 1867), also speaks of the valvular projections of these veins at the point of their discharge into the long sinus.

In injecting from the jugularis, one never succeeds in filling more than a very few of these veins, and such but a short distance.

The anterior veins are more apt to be thus partially injected than the posterior ones. To study this valvular action in another way, the following experiment was made: From an intact skull the soft parts were removed, and, from one side of the cranium an oval piece of bone, reaching from the middle of the occiput to the frontal bone, was carefully sawed out. The opening thus made had a width in the middle of perhaps 4 cm. The canula of a syringe was tied into one of the jugulars near the base of the skull, and the other neck veins as far as possible ligated. The external layer of the dura (see note to p. 18) was prepared off, that the underlying veins might be better seen. In this way the movement of the current in the superior veins could be readily followed. Water was then injected through the canula. At first the little quantity of blood in the veins walled back a trifle, after which, even under a considerably increased pressure, it remained still. On pulling back the piston the stream moved a little towards the sinus. On pressing again it walled back a trifle as before. The syringe was then pressed as hard as possible, whereupon the stream ran back a little farther into the veins, but only under a pressure which could hardly occur in the

[1] The word parasinoidal which I have proposed (*l. c.*, p. 273), for these spaces, although a Latin-Greek combination, is so euphonious, and at the same time strictly correct in meaning that it may, perhaps, be pardoned. The term which I find given them by Key and Retzius—*lacunæ laterales sinus*—is, however, non-exceptionable unless for its length. These spaces must not be confounded with the sini subalterni (Malacarne referred to by Knott), which run parallel to the sinus, usually below it in the falx.

living subject. The conditions in this experiment were, after all, not the same as under an intact skull. The areolar venous spaces along the sinus, (*lac. latl. sin.*), as described by Trolard and figured by Langer, may also participate in this valvular action, or at least on filling, interfere with any reflux in the veins passing through or near them.

These spaces are however not limited to the middle of the sinus longitudinalis as from Langer's description, one might be led to think. He states that they may occur not only beside the said sinus, but also in the falx cerebri directly under it. (Perhaps the sini subalterni referred to above).

These parasinoidal spaces had been often seen and referred to (cf. writings of Cruveilhier, L. Meyer, Luschka, Henle, etc.), before the above-named writers, but they described them more fully, and as constant structures, so that the formations have now an acknowledged position.

Alveolar spaces exist on both sides of the long sinus in nearly its whole length.

They can readily be injected from or with the sinus. These are most developed, it is true, opposite the middle of the sinus, but are readily demonstrable all along it, also on both sides of the sinus rectus, and even in the tentorium cerebelli, beside the transverse sinuses. In all these places they lie between the layers of the dura, just as these are separating to form the sinus walls.

Ib. The veins of the dura mater.

These veins empty in part into the sinus longitudinalis, in part in other directions.

Two vascular nets are described by Langer and others, one in the inner layer of the dura, and another in the outer layer. The larger dural veins however lie between these two parts, or, according to Key and Retzius (*l. c.*, p. 163), more in the outer layer.

The dura veins communicate freely by means of small veinlets penetrating the inner plate of the skull with the

diploë veins, and, according to Langer, sometimes directly with those of the convexity. Macroscopically, they are small, the largest barely the size of a knitting needle, and are not uniform in their deportment:

1. Such as accompany the arteria meningea media and its branches. These are nearly all double, one on each side of the artery, and frequently connecting with each other, or with other veinlets in the vicinity.

2. A large number of small trunklets, which, after a short course in the dura, reach one of the sinuses. The long sinus receives the largest number of these.

3. According to what was found on a dura mater from a new born child, there may be farther back on each side a well developed vein. This was larger than any other in the same dura. It arose at about the parietal eminence, and flowed towards the transverse sinus. Its smaller branches anastomosed with those above described, and sent substituting branches in place of many of the veins accompanying the rami of the middle meningeal artery. In its farther course towards the sinus, the vein ran on one side under, on the other over the branches of this artery. This vessel was readily traceable to about the middle of the lambda suture, from which point on it was difficult to follow.

There are also veins in the falx cerebri.

All of these dura veins anastomose so freely with one another, that they might almost be denominated a plexus.[1]

The dural veins are much easier to follow in the infantile

[1] It is very natural here to make a comparison, with the plexus venosus existing between dura and periosteum of the spinal canal. The two membranes are, as is well known, not adherent as in the cranial cavity. The spinal dura is free, thus allowing flexibility to the spinal column.

The cerebral dura, and still easier its processes may be shown to consist of two layers Most anatomists refer to two chief layers of the cerebral, dura. Between these lie vessels which remind us of the spinal plexus.

The principle of the formation of the blood-sinuses depends in general upon the separating apart of the inner and outer lamellæ of the dura

subject, partly because its dura is more transparent, partly because it is without doubt more vascular, a circumstance to which Langer also refers.

Ic. The Emissaria Santorini do not belong farther to our subject. It is worthy of note that they also occur in pairs, terminating in the sinus longitudinalis, and that the pair of emissaries, most constant in its occurrence, ends in the sinus about opposite the last pair of superior cerebral veins, or, according to Henle, about 20 mm. in front of the postetior upper angle of the parietal bone. They terminate in the sinus similar to the dural veins, of which they often take up some. Moreover, it is important, in considering the local venous circulation, to bear in mind that, according to Langer, valves may occur at the exit of the diploë veins (Brechet's) from the skull, preventing the flow from the surface of the cranium towards the sinus. This tends to show that the emissaria are efferent vessels.

There is another outlet, the emissarium occipitale, very similar to these through the parietal foramina. This passes from the torcular through the protuberantia occipitalis to the occipital veins. Henle says its course is usually somewhat sinuous, and that it takes up the azygoid trunk of the venæ diploicæ occipitales. Knott found this emissary as a small but traceable vein in six out of his forty-four cases. In most of the others there was a small vein piercing one of the bone-plates and anastomosing with the diploë veins.

mater, as explained by Luschka. Here they lie more protected, and this gives them their general triangular form (in section).

The various internal processes of the dura (falx, tentorium, etc.) represent duplicatures of its internal layer. Apropos, Key and Retzius (*l. c.*, p. 126) consider the pia and arachnoidea as one membrane, consisting, in addition to the two parts named, of a third called by them subarachnoidal tissue. Batty Tuke (*Edbg. Medical Journal,* June, 1882) comes, apparently unconscious that he had been anticipated, to the same conclusion, and quotes a comparison made to him by Symington between the duplicatures of the inner part—*i. e.*, the folds of the pia where it dips into the sulci—and those of the inner dural layer just mentioned.

I have a good specimen of this from a male subject of twenty-nine years. Where the longitudinal sinus turns into the right lateral there is a well-marked opening large enough to pass a good silver probe, and, despite the thickness of the bone at this point, 1¼ cm., so straight that one can readily look through it. A vein from the sinus to the veins of the scalp quite filled the space. Externally there is but one opening; internally there are, besides the main one, several smaller openings. On plugging the main internal one, and letting water in at the external one, it flowed out again through the accessory openings on the inner surface. These doubtless communicate with the diplöe veins.

II. The Middle Veins of the Brain (venæ cerebri profundæ, vv. cerebri intimis, Galen's System of Veins). The sinus rectus takes up several vein-trunklets in its course between the tentorium cerebelli and the falx cerebri; these are, however, insignificant, and come mostly from the dura. Laterally from the sinus rectus, where the two wings of the tentorium are attached, there are alveolar venous spaces demonstrable by means of injections, although on a smaller scale than along the sinus longitudinalis.

Galen's system of veins empties into the sinus rectus at or near its forward end. Here the conditions deviate very remarkably from the customary illustrations and descriptions. There seems to be no correct description of this part extant, and only one passably correct representation—viz., Breschet, 8*e*. Livr., Planche 47, Fig. 1.

In the first place the sinus rectus does not form a straight, or even nearly straight, continuation of the vena Galeni [1] (*s*, Fig. 2).

The course of the vein followed out from the sinus is first a short distance backwards and somewhat downwards directly beneath the sinus, under cover of the sloping wings of the tentorium, then sharper downward and forward, circling around the splenium corporis callosi, and finally upward over the central posterior portion of the thalami optici and the third ventricle.

[1] This fact had already been observed by Prof. Braune before I began my injections.

Secondly, the so-called sinus longitudinalis inferior (s. falciformis inferior), although always pictured, is of comparatively rare occurrence.

In seven adult brains examined for this, only twice was any trace of it to be found even where the more difficult bend in the vena Galeni was well filled.[1] It is not difficult to make an artificial sinus by thrusting a small sound through the forward end of the sinus rectus, and then pushing it on between the layers of the falx cerebri.

In the fœtus there is usually nothing of the kind to be found, but inasmuch as the fœtal dura is more vascular, there lies, often and naturally enough, some irregular vein near the lower edge of the falx cerebri.

Amongst five or six fœtal duras examined, there was not one where this sinus was well marked.

Trolard (*l. c.*, p. 261–2), has a considerable to say about this part without, however, enlightening one very much. He had observed anastomoses connecting the two longitudinal sinuses. He lays great weight upon a possible substituting action in consequence of this, or, more fully expressed, in case of obstruction to the circulation in the sinus rectus or s. lateralis, the vena Galeni would still have a way of discharging.

This is most assuredly pure fancy. Such very rare anastomoses, for one finds them occasionally pictured elsewhere (*e. g.*, in Heitzmann's atlas), may possibly have a very different—viz., embryological significance (see below). Certain veins will soon be described, which take a course similar to this so-called sinus. Knott says that in three of his cases, where there was but a very small longitudinal sinus, its usual tributaries turned down between the layers of the falx cerebri to the inferior sinus.

[1] Since then I have examined between ten and fifteen in this respect, with the result of finding it fairly indicated in one.

In two cases, the straight sinus received the termination of the superior longitudinal, which did not groove the occipital bone for the last inch of its course, but turned a little forwards and downwards likewise between the layers of the falx.

Here belongs also a quotation of Luschka's from Portal, referring to the consort of Louis XV. After suffering for years from headache, she died of general dropsy. The autopsy showed a completely obliterated and partly ossified superior, but a wide inferior longitudinal sinus.

The sinus rectus extends in full size, to just in front of the mouth of the vena Galeni, and then ends abruptly (Figs. 1 and 2).

The opening through which this vein enters is a slit looking downwards and a little forwards. This slit or portal passes longitudinally through the tentorium cerebelli in its median line. It begins directly back of the point where the under edge of the falx cerebri, and the front edge of the tentorium meet. It starts therefore right behind the point of the incisura tentorii. Thus a strong band is formed across the front end of the cleft, which prevents its gaping. In situ the slit is narrow and antero-posteriorly about one-half cm. long. On drying the tentorium, or cutting it out and pulling at its two wings, the opening gaps much wider than in the natural state.

The name vena Galeni appears to be now limited to the short common vein-trunk next to the sinus rectus. This trunk has, according to Quain-Hoffmann (*Anat.* Ed., 1878), a length of about 1 cm. and breadth of 6-8 mm. Luschka gives its length as 8 mm. and breadth as 5-6 mm., and says it is often divided internally into two halves by a longitudinal septum.

Near its mouth, however, it is wider antero-posteriorly, and at its origin wider from side to side, so that the measures of breadth quoted can be considered only very general

and are, I think, too large. The vena Galeni receives no side branches, and its inferior or peripheral end arises from two veins, the *venæ cerebræ internaæ, dextra et sinistra* (Fig. 1, *cc*).

Each of these veins may be considered as consisting of two portions, of a posterior bent portion (*portio curvata*)[1] extending from the glandula pinealis to the sinus rectus, and of an anterior straighter part (*portio recta*), running from its origin at or near the front end of the thalamus opticus, between the two thalami to the glandula pinealis. The two curved portions are at both ends together, but in their middle part they diverge 0.5-1.0 cm. They receive laterally many large branches. The straight portions, on the other hand, receive but few and small additions in their course.

The vein-trunks taken up by the curved portions are (Figs. 1 and 2):

1. Vena cerebelli superior.
2. Vena occipitalis interna.
3. Ramus corporis callosi posterior externus (new).
4. Vena basilaris Rosenthali.
5. Rami corporum quadrigeminorum.

These last are taken up either by the vena cerebelli superior (1 above) or by the main trunk.

6. Vena cornu posterioris and the vena basilaris adjuncta (both new).

1. The vena cerebelli superior media (Fig. 2, *i*), more often single but occurring occasionally on both sides, empties into one respectively both of the main veins just before their ending in the vena Galeni. This vein arises from many little branches in the pia on the surface of the cerebellum, runs forward, settles often a little into the fissure between cerebellum and crura cerebri, receives several branches

[1] Since these two parts as such have never before been described, the terms portio curvata, and in opposition thereto, portio recta, are here used. It will presently be shown that this division into the two parts specified is of considerable importance.

which come out at this point, and in its farther course takes up some little veins from the crura cerebri on both sides, whereupon it ascends perpendicularly to its termination. It collects the blood, therefore, from the upper and front parts of the cerebellum, besides taking up, in many cases, branches from the corpora quadrigemina. According to Henle, it sometimes empties directly into the sinus rectus.

2. Vena occipitalis interna (vena cerebri posterior inferior, probably the rami posteriores superficiales of Rosenthal). Fig. 2, *h*.

There is one such vein present on each side. It has a thickness of 1-2 mm., and starts from the fissura collateralis. It is made up from the bottom and sides of this fissure, and from the central part of the under surface of the occipital lobe.

3. Vena corporis callosi posterior externa[1] (Figs. 1 and 2, *g*). These do not seem to have found any notice heretofore. They are small trunks, one on each side and the only ones that empty on the concave or front side of the portio curvata. They come down around the splenium corporis callosi, and lie in this part of their course close beside or in front of the vena Galeni, between it and the splenium. Their origin is near the middle of the corpus callosum, and upwards as far as the fissura calloso-marginalis. They then course posteriorly in the pia mater at each side of the bottom of the great longitudinal fissure.

These veins take up about the same tract that was presumably attributed to the sinus longitudinalis inferior.

4. Vena basilaris Rosenthalii (vena cerebri inferior).[2] Figs.

[1] It is assuredly more rational, here and at the anterior end of the corpus callosum, to speak of external and internal to the corpus callosum than, as was the custom so far as these veins have been described in the past, to speak of superiors and inferiors, for as well anteriorly as posteriorly the so-called superiors begin above but end below.

[2] Vena basilaris is most certainly preferable to vena ascendens, a term which has been applied to this vein, since it, as will be shown, often does not ascend at all, but is in all cases a basal vein.

1 and 2, *c*. This vein was first specially described by Rosenthal, after whom it is often named. There is one on each side, but the extent of its territory is very variable. We will first describe it in the largest extent in which it occurs. These two veins are the strongest contributing branches of the venæ cerebri internæ. As above indicated, the internæ separate somewhat from one another laterally in their bent portion. A little back of where they are farthest apart the vv. basilares empty. Each joins itself so to the outer side of the curve that it represents more nearly a direct continuation of the posterior portion of the curve than the vena interna itself, and it is, moreover, frequently of about equal size. They form, by the union of many branches, near the inferior end of each Roland's fissure, opposite the substantia perforata anterior, and run along the base of the brain backwards across the crura cerebri, then upwards through Bischat's fissure to their destination back of the corpora quadrigemina. One can get sight of this vein on the base of the brain by pulling the edge of the temporal lobe a little to the side. They are external to their respective optic nerve at the point, back of the chiasma, where they cross it. These collective branches may well be termed *venæ anteriores basilares*.

Of these the most constant in their occurrence are:

a. Vena fossæ sylvii.

b. Rami perforantes.

c. Venæ lobi anterioris inferiores.

d. Ramus olfactorii (new).

e. Vena callosi anterior externa.

a. The vena fossæ sylvii [1] is usually the largest of these, and thus represents the continuation of the vena basilaris. It lies at the bottom of the fissure, covered up,

[1] In regard to confusion in the use of the terms vena fossæ Sylvii, vena cerebri media, and vena anastomatica magna, see p. 38..

except near its termination, by the front edge of the temporal lobe, and sometimes consists in its upper part of two principal branches. It arises in the region of the island of Riel from a great number of little branchlets coming from all directions. Now and then it takes up little twigs from the surface of the temporal and frontal lobes. Some of the perforantes pass, as a rule, to this vein; indeed, there is often a group of perforating veins a little separated from the others and coming from parts of the medulla behind the vena fossæ sylvii.

b. The perforantes are small, very variable in number, and take a straight course. They originate in the inner ganglia, especially corpus striatum and nucleus lentiformis, a few, however, coming from parts in front of these. They can be followed 2–3 cm. and then gradually branch off. Here they lie close to the radicles of the vena cornu anterioris presently to be described, and yet without any observable anastomoses.

c. Rami lobi anterioris inferiores. These are from the inferior surface of the frontal lobe. One such vein, lateral to the olfactory groove, is frequently more developed, and may empty directly into the vena fossæ sylvii. The rami collect from the pia of the region mentioned quite as the venæ superiores do on the upper surface of the brain.

d. Ramus bulbi olfactorii. This is a tiny branchlet in the olfactory groove, very constant in its occurrence and demonstrable as far as the bulbus olfactorius.

e. Vena corporis callosi anterior externa. This takes very nearly the same path as the arteria cerebralis anterior. It is too small and uncertain to be well compared to the artery, and its distributions is to a much more limited area. The vein comes around the genu corporis callosi to the base of the brain, where it passes before the chiasma to the vena basilaris. The two veins—right and left one—are usually

of unequal size, but communicate with one another. This has been compared to the commissure between the two anterior cerebral arteries, but the venous communication is far from being as well marked. The two veins may unite before the chiasma and pass to one of the venæ basilares; even then there is one or more connections in front of the chiasma with the basilaris of the other side. This vein receives branches from the opposed surface of the anterior lobe—*i. e.*, from the longitudinal fissure in its anterior third, and from the corresponding part of the corpus callosum.

Rosenthal speaks of a vein, and Trolard of small veins, back of those just described, in other words, between these and our posteriores of the same name. Such intermediary veins came from the middle or front part of the corpus callosum and neighboring convolutions, and passed to the front end of the sinus longitudinalis inferior. These probably occur only when such a sinus exists, which has been shown to be very inconstant. Among the adult brains examined for them, but one had these veins appreciably developed.

The basilaris, from the anterior perforated space on, receives several small vessels from chiasma, hypophysis cerebri, substantia perforata posterior, crura cerebri, etc. These anastomose freely with each other and with those of the other side, thus making a network over these parts, which communicates in front with a small network before the chiasma and posteriorly with that over the pons. This connected network is not interrupted by sulci, as it is over the rest of the cerebral surface. In fœtal brains, however, the pia does not pass down as far into the sulci, and a somewhat similar appearance is presented by the whole surface.

At least one accessory branch larger than the others comes out of the substantia perforata posterior. The largest branch to the basilaris in the remainder of its course is

one from the inferior end of Bischat's fissure, respectively of the inferior horn of the lateral ventricle. There are oftentimes little veinlets coming from the inferior surface of the temporal lobe, external to the lower end of the said fissure. But the main branch is larger than these—about the size of a knitting-needle—is very constant in its occurrence, and comes from the middle cornu of the lateral ventricle. Since this vein has never before been described, I have called it vena cornu inferioris. In previous anatomical descriptions it has been stated that the vena basilaris sometimes receives branches from this vicinity. Only in Trolard's article (see below) is there a probable reference to the v. cornu inferioris under "*une petite veinule au plexus choroide.*" But this vein, as will be shown, does not have its chief origin in the plexus choroïdeus, but in the cerebral substance itself. It corresponds, evidently, to the arteria choroidea, which, according to Heubner, comes from the arteria fossæ sylvii or carotis cerebralis.

The district belonging to this vein is variable. Sometimes the vessel begins far back in the posterior cornu of the lateral ventricle. It often receives branches in the vicinity of the thalamus opticus, which come a distance of several centimeters from the medullaris lateral to the thalamus, or it may at the same point receive branches from above.

The said vein receives very numerous accessions along its whole course, be that shorter or longer. These are mostly lateral shoots coming out of the brain matter. The vessel itself lies usually on the outer wall of the horn, as far as the lower end of the same, where it passes around to the front wall. Here it takes up several little twigs from the adjacent parts of the brain, especially those in front of it, and at length passes back and inwards to the vena basilaris. Henle says that the vena choroidea (an accessory of the vena in-

tima cerebri) anastomoses with the external veins at the anterior end of the lateral horn. Probably this would be with the v. cornu inferioris just described. Such anastomoses at the lower end of the horn seemed in several of the present cases to exist, but were in no one of them so well injected as to be demonstrable.

The basilaris as it crosses the crura cerebri receives many little veinlets. One, however, is somewhat larger. It lies on the outer surface of the crus, often in a shallow groove, and comes from the cerebellum (flocculus). All these collect blood from the vicinity of the crura cerebri.

5. Rami carporum quadrigeminorum, azygos conarii, etc., from the conarium and corpora quadrigemina, as shown by Rosenthal. They empty, as noted above, either directly into the portio curvata of the vena intima, or into the vena cerebelli superior. They originate in a plexus of fine veins on the surface and vicinity of the corpora quadrigemina. This plexus appears to be in connection across the crura cerebri with the network on the base of the brain described above. In other words, while it belongs to the general venous network of the pia, it belongs more strictly to that part which is stretched out with but few interruptions.

6. Vena cornu posterioris (Fig. 1, *q*), to which may be reckoned the occasional vena basilaris adjuncta. These may be in part what Rosenthal designated as rami plexus choroidei posteriores.

As a rule, though not very constant, there is another large vein tributary to the vena intima cerebri. It approaches the main trunk laterally, and lies in about the same plane in which it empties. It arises chiefly in the posterior horn, a minor part, however, comes from the medullaris, anterior and lateral to the cornu ammonis. The main trunk often begins in the substance back of the tapered out end of the posterior cornu, and runs forward just under the ependyma

in the wall of the horn, taking up tributaries from the medullaris all the way along. Its radiate branches are preparable nearly to the gray cortical layer. Across the posterior end of the thalamus opticus, any branches which may so far have kept separate, approach and unite with smaller ones which often come from the cornu ammonis and adjacent parts. The extent of distribution of the vena cornu posterioris and of the vena cornu inferioris seems to be complementary. Where the one vein is more markedly developed, the other will be correspondingly less so, and *vice versa*. Sometimes, however, there occurs a kind of intermediary form, which might be named ramus basilaris adjunctus. In these cases a vein trunk either comes from the inferior horn to the vena cornu posterioris, or passes through the middle of Bischat's fissure to the vena basilaris itself. This branch may be quite large, and originates in the upper part of this cornu. The termination of such a vein is shown on the left in Fig. 1.

To turn back now to the internal veins in the strict sense, with which certainly some of those already described are to be classed. These veins do not all lie in the same plane, although it may appear so in an illustration.

The veins taken up by the portio recta, beginning at the posterior end and reckoning forward, are:

1. Venæ callosi posteriores internæ (*new*).

2. Vena pedunculi cerebri. (Ramus thalami optici profundus.)

3. Rami thalami optici ; vena lateralis directa.

All of these little veins empty at a right angle to the current.

1. The branches from the corpus callosum (Figs. 1 and 2, *f*) are very small, and but two or three in number at the point where they emerge from its substance. They often

combine with other little veins from the thalamus, and empty as one trunk into the vena intima. These veins are specially destined for the splenium corporis callosi.

2. Ramus thalami optici profundus (Rosenthal) Fig. 1, *m*. This is usually represented by one trunk on each side, but sometimes there are several. It begins, as described by Rosenthal, down about the crus cerebri, makes its way through the thalamus upwards and inwards, and joins the portio recta at about its middle point. It approaches from beneath in such a way that it is but too easily overseen.

3. Rami thalami optici, etc. (Fig. 1). In number, size, and position, these veinlets are very irregular. They may even be entirely wanting, or run to the more anteriorly situated veins, or indeed to the above described vena cornu posterioris. In Fig. 1, *r*, there is one of the veins at the left much larger than the others, and about which more will be said. This particular one might be termed Vena lateralis directa.

The rami thalami optici start to some extent from the thalamus, but chiefly from the medullaris beyond the thalamus, and then run across, or a trifle imbedded in it, to the main vessel.

The beginning of the Vena intima cerebri.

At the front end of the thalamus opticus, several veins (Fig. 1) unite to form the said trunk. In general there are two clusters of veins from different directions an anterior one between the septum pellucidum and the corpus striatum, and a lateral one between the striated body and the thalamus opticus. The corpus striatum is always very rich in veins. Many of the said branches come from that alone ; others of considerable size come from the roof of the ventricle and pass across the striated body.

A deviation from former descriptions, and even a certain

asymmetry, is noticeable in the veins of this region. The various writers have clung fast to a vena reflexa lateralis (s. vena terminalis). It is represented as a continuation of the vena intima cerebri, bending around the front end of the thalamus and (traced peripherally) running back under the stria cornea between corpus striatum and thalamus to the lateral horn of the ventricle. Such a course would be more or less parallel to the vena choroidea. Although this may occasionally occur, it is far from being the rule. Many times a small branch does start some way back, but not exactly in the specified groove, the rather on the outer edge of the ventricle. This vein or branch in about an even number of cases reached not more than half way back to the inferior horn.

The asymmetry in the cases examined consisted in this: that either the vena lateralis ventriculi (so-called vena reflexa) on the left side crossed over the anterior third of the thalamus to about the middle of the portio recta, and that it therefore united more posteriorly with the vena anterior ventriculi to form the portio recta than the corresponding vein on the right side; or there was on the left side a second strong vessel farther back. This latter has already been mentioned above as vena lateralis directa. Whether this relation—viz., a straighter course and perhaps larger size on the left side—would prove to be constant in a larger number of cases, can scarcely be asserted. Still, so much is sure, [a] that the so-called reflexa does not always bow around the front end of the thalamus, and [b] that the two laterales, even in the same brain, are not symmetrical. Moreover, the rami septi pellucidi, so-called, are at least falsely named, since they come only to a very small extent from the septum, and sometimes do not so much as lie upon it.

The radiating veins and their branches, which go to make up the vena cerebri intima at its anterior end, may be classified as follows:

a. Vena lateralis ventriculi.
1. Vena choridea.
2. Rami carporis striati.
3. Rami laterales posteriores (*new*).
4. Rami laterales anteriores (*new*).

b. Vena anterior ventriculi.
5. Venæ medullares superiores (these run in part to No. 4) (*new*).
6. Venæ cornu anterioris (*new*).
7. Rami septi pellucidi et rami callosi anteriores internae.

a The vena lateralis never receives more than small shoots from the thalamus, and such but rarely.

1. The vena choroidea (Fig. 1, *l*), empties into any one of the veins laterally from the crura fornici. It takes a sinuous course along the outer edge of the plexus choroideus of approximately double the actual distance. It begins in the plexus of the inferior cornu, rises out of the horn and bends forward and somewhat centrally over the thalamus. Meanwhile, it receives a great many tributaries from the plexus. These appear to collect blood from the surface of the optic thalamus, as do the pia veins from the external surface.

The similarity between the two is increased by the fact that plexus and tela are processes of the external pia. It would clearly be more correct to hold the vena choroïdea than the vena lateralis to be the continuation of the vena intima.

2. Rami corporis striati (Fig. 1). Of these there are usually two or three larger and several smaller ones, which come from the substance and surface of the striated body.

3 and 4. The vena lateralis, either as far out as the edge of the ventricle or else close to the vena intima, is made up of two trends of veins: first, a posterior one lying over the tail of the corpus striatum, rami laterales posteriores; secondly, an anterior trend running near the outer edge of the anterior horn, rami laterales anteriores (Fig. 1.) On following these into the medullaris, one finds a host of branches, some from the medullaris above, from the roof of the ventricle, etc., others arising from parts below, which may be followed down 2–3 cm., and still others aimed straight out towards the surface. Posteriorly they seldom reach as far as the entrance of the inferior cornu. But many of the anteriores reach far out through the anterior lobe, nearly or even quite to the corticalis.

Taken together, therefore, the branches of the vena lateralis are distributed upwards and downwards, outwards and forwards, in part even to the gray cortical layer.

b. The vena anterior ventriculi (Fig. 1, *o*) unites with the lateralis occasionally opposite the crura fornici, but often farther back. The name and the vein as here described are new. It presents a single, very constant trunk of 1 cm. or more in length. It is formed by the union of the two venæ cornu anterioris, and merges with the vena lateralis to form the vena intima cerebri.

5. Rami medullares superiores (Fig. 1, *nn*). There are usually two or three of these which lie across the corpus striatum. These and the smaller ones from the rami laterales anteriores are scattered out through the medullary substance as far as the cortical layer.

6. Venæ cornu anterioris (Fig. 1, *pp*). There are usually two on each side, which by their union form the vena anterior ventriculi. They start from the farthest corner of the anterior horn, the front contour of which they follow around to the septum lucidum, where they unite as stated.

They run almost parallel, one a little above the other, and both imbedded under the ventricular ependyma.

Occasionally, however, they cross over the front part of the striated body, likewise in or beneath the ependyma. As regards direction they form, in connection with the vena anterior ventriculi, the most direct continuation of the vena intima.

These veins rarely receive any additions from the corpus striatum. The most of their tributaries are distributed forwards and downwards, only a few upwards. An innumerable mass of branches meet together at the outer end of the anterior horn ; others add themselves to the veins in their farther course. These come in pretty straight courses from the periphery, and are demonstrable everywhere in the lower part of the anterior lobe, nearly to the gray cortex.

7. Either to the vena anterior ventriculi directly, or to the venæ cornu anterioris, run several tiny branchlets from the substance of the septum and adjacent part of the corpus callosum. These, and these alone, deserve the name rami septi pellucidi, resp., for a portion of them, rami corporis callosi anteriores internae.

III. Veins of the base of the brain.

The veins at the base present no single uniform system like that of Galen or of the superior veins. They have already been treated of in part under vena basilaris Rosenthali.

They present a great many irregularities in course and termination. It is customary to include most of the cerebellar veins in this division. There are, however, three points on each side, towards which, to a certain extent, all these veins aim—viz. :

1. Middle of the sinus transversus.

2. Region of the flocculus or front end of the sulcus magnus horizontalis of cerebellum.

3. Inferior end of the fossa sylvii. But at any point of the basal sinuses small veins seem occasionally to terminate.

1. Seemingly constant are the veins from cerebrum and cerebellum, which discharge near the middle of the sinus transversus—viz.:

a. Venæ occipitales laterales.

b. Venæ cerebelli laterales.

a. These are surely identical with Trolard's "veines cérébrales latérales et inférieurs." They are usually united to one trunk before they reach the point, where, passing backwards, they perforate the sinus wall. Some small branches come from the inferior surface of the occipital lobe. These latter carry off the blood from the tract external to the vena occipitalis interna, which empties into the vena intima cerebri. The chief trunk of the vena occipitalis lateralis lies, however, in the direction of the upper end of the fossa sylvii. Anteriorly it receives some smaller branches from the temporal region, and posteriorly some larger ones from the occipital lobes.

b. The venæ laterales cerebelli are smaller, and lie, of course, below the tentorium cerebelli. They often empty into the sinus transversus at the same point as the just described Vv. occipitales. Trolard also makes a similar statement. They come from the adjacent parts of the cerebellum. Mention should also be made here of the occasional though far from constant occurrence of one or more venæ posteriores cerebelli emptying into the sinus transversus. They ascend from the posterior surface of the cerebellum and end in the sinus, laterally from the torcular Herophili.

2. Venæ flocculares (*new*).

Here we come into the territory of the vena basilaris. It often occurs that this latter vein does not take an upward course to the vena intima (Galen's system), al-

though this is the only course heretofore ascribed to it, but after receiving the v. cornu inferioris, or indeed in some cases consisting of that alone, it strikes downwards on the respective crus cerebri, and empties with the venæ flocculares on the base of the brain. In this case it takes the path described above (p. 29) for the ramus cruris cerebri, a tributary of the basilaris when the latter takes its more usual course. It is probable that the just mentioned veinlet communicates regularly with the venæ flocculares,[1] and also that, when the basilaris takes the lower course, it still communicates with the venæ corpora quadrigeminæ by means of small but constant posterior branches. But whatever course the basilaris takes, several cerebellar veins unite in the vicinity of the flocculus, and empty forthwith into one of the petrous sinuses. These veins come chiefly from the sulcus magnus horizontalis, where they collect a great number of side shoots. There are also smaller branches from the region of the medulla oblongata, the pons, etc., on all of which parts they are the outlet of the venous pia-net. Smaller veins from the pons may empty independently, and then even into other sinuses.

3. Veins which direct their course towards the lower end of the fossa sylvii.

The description of the basilaris, as given on p. 25, holds for something like half the cases, but for the other half it does not hold or only in part.

In six out of the ten venæ basilares examined, the Vv. basilares anteriores terminated in some one of the sinuses of the base, either at the end of the fossa sylvii immediately in a branch of the cavernous sinus, or after uniting and taking up the vena cornu inferioris, they emptied as the real vena basilaris, beside the flocculus.

The venæ anteriores discharge in the first case with

[1] An observation of Trolard's (see note to p. 42) corroborates this.

the vena cerebri media. This vein does not lie so deep in the sulcus as the vena fossæ sylvii, and is moreover occasionally double—*i. e.*, there are then two parallel veins lying close together, one taking up anterior branches, the other posterior. It begins about the upper part of the fossa where it gathers branches from all directions, and collects along its course many tributaries from the temporal and frontal lobes (rami superficiales lobi temporalis et lobi anterioris).

Where this vein is double, the anterior one of the two may take up the venæ basilares anteriores and empty into the external prolongation of the sinus cavernosus (sinus spheno-parietalis, s. alæ parvæ), while the posterior one runs backwards in the dura beneath and around the temporal lobe to the middle of the sinus petrosus major. This latter is the same course that the whole vena cerebri media takes in many cases, as Trolard rightly says.

It would appear as though the terms vena fossæ sylvii and vena cerebri media were used as identical. While an exact discrimination between the two is, it must be acknowledged, not always possible, still the name vena cerebri media is decidedly more applicable to the superficial vein just described and the term vena fossæ sylvii should be restricted to the deeper lying vein which usually goes to the basilaris. The two are more or less complementary in size, territory, and even occurrence, sometimes one being wanting while the other is correspondingly larger. Trolard found the vena cerebri media (called by him *la grande veine anastomotique*) twenty-five times amongst thirty subjects, whether on both sides, or only on one, he does not say, although the two sides of the same brain may differ in this regard. Some small veins from the chisama, pituitary body, tuber cinerium and infundibulum have been described as tributary to the sinus circularis Ridlei.

The veins of the cerebellum, classed together, show the following. They may empty into the numerous sinuses of this region at any point, as was specified above, for all the veins of the base. Arranged according to the part where they originate, there are:

1. One or two venæ cerebelli superiores mediae (p. 23, 1), which go to the vena intima cerebri. Here belong also any smaller veins which end directly in the sinus rectus, into which, as already noted, the vena cerebelli superior is said to occasionally empty.

2. The floccular veins (p. 36, 2).

3. The venæ laterales et posteriores, which run to the sinus transversus (p. 36, *b*).

These veins have all been described above. Certain other smaller cerebellar veins, lying in the vicinity of the foramen magnum, are mentioned by some anatomists. The occipital sinus connects with the vertebral veins by means of the two condyloid foramina (Harrison, *Anat.*, 1855,) as also with the subcutaneous veins of the upper cervical region (Luschka, etc). The two small, central spinal veins, as given by Krause, divide and scatter at their upper end—*i. e.*, beneath the calamus scriptorius, each side of the median line on the base of the fourth ventricle.

Oegg's work, "*Untersuchungen ueber die Anordnung und Vertheilung der Gefässe in den Windungen des kleinen Gehirns, Aschaffenburg*, 1857," was not accessible to me.

Langhan's theory (*Virch. Archiv.*, vol. lxxxv.)—which has not, so far as I am aware, met with much favor—that syringomyelia of the superior end of the spinal cord sometimes results from hindrance to the venous discharge, would necessitate the assumption that the blood in the upper part of the central spinal veins flows toward the brain and into its sinuses. He gives in corroboration several cases of his own observation where tumors in the vicinity of the fourth ventricle, pressing strongly down against pons and medulla oblongata, have apparently led to this condition.

Sanders quotes from Richardson a case of attempted suicide by hanging, resulting in death three days later, where an extensive effusion was found

in the cerebral ventricles with a most intense congestion of the cerebrum, presumably venous, while the cerebellum was scarcely affected. This would indicate a certain independence of the blood-discharge from the cerebellum, and perhaps to some extent from the near, so-called vital centers, secured by the communications between the occipital sinus (sin. circularis foraminis occipitalis) and the spinal and nuchal veins.

COMMUNICATIONS.

I. Between dural and cerebral veins.

From the description of these veins already given, it is evident that a communication between these two sets occurs within the cranial cavity. This is accomplished in quite an extensive manner by means of the sinus longitudinalis.

All writers agree that the vena meningea media communicates with or empties in part into the vena cerebri media resp., the lateral prolongation of the cavernous sinus (sin. alæ parvæ), which also receives the vena diploica anterior (Luschka) and Hyrtl's vena ophthalmo-meningea; that on the other hand the remainder of the v. meningea media passes through the spinous or the oval foramen to the maxillary or pterygoid plexus (See, Hyrtl).

Further, Knott says "An additional tributary to the cavernous sinus, in the form of an emissary vein passing through the canalis rotundus of the sphenoid bone in company with the superior maxillary nerve, has been described by Nuhn." He (Knott) has seen this twice, both times on the right side. He also refers to Nuhn's description of a pair of veins communicating with the middle meningeal veins, and which, after passing through the foramen ovale and forming a plexus around the commencing portion of the inferior maxillary nerve, terminate in the venous plexus of the infra-temporal fossa. Knott found these veins in eighteen cases on both sides. In six other cases there were two veins right and one left; in four the condition was reversed; in eleven a single vein on each side; in five there was no vein on one side, three of these being on the right.

From all this it follows that there is a communication at the base of the temporal lobe between dura and pia veins.

Finally, Langer has seen "veins which leave the brain in the vicinity of the parietal bone, so that thereby a connection is produced between hemisphere and dura-capsule far

away from the sinus." Such are, however, unusual—probably of pathological origin.

With regard to the arteries we find, on contrasting them, that any communication between those of the dura and those of the pia and brain proper is far from certain. Heubner (*l. c.*, p. 172) says that "the territories of the arteria meningea media and of the cerebral arteries must be considered as absolutely independent of one another."

On the other hand Langer, in his still more recent work, describes one or two meningeal branches of the arteria cerebri anterior, which anastomose in the falx cerebri with some from the meningeal artery, and also with others which accompany the superior cerebral veins as they spring over to the dura near the sinus longitudinalis.

These two, Heubner's and Langer's, seemingly contradictory statements can perhaps be harmonized, inasmuch as Langer drew his descriptions from infantile and young subjects, while Heubner's injections were on adult organs, and, as we have indicated (p. 19), the infantile brain, and especially its envelopes, are more highly vascular than are those of the adult. So much can be safely stated, that the *arterial communications, if they exist at all in the adult, are far less pronounced than are those of the veins.*

II. Communications between the cerebral vessels themselves.[1]

Expressed in general terms there exist very numerous anastomoses between all the superficial veins, but not between the strictly internal veins. From this there arise two great classes:

A. Class of superficial or pia veins.

B. Class of internal veins.

A. The superficial or external vessels.

On injecting a solution of Berlin blue, or, still better, Pansch's material, into any convenient superficial vein, it is seen that the small vessels form a complete net in the pia, freely anastomosing everywhere on the surface.

The words of Heubner (*l. c.*, p. 174) in regard to the surface arteries are quite as applicable to the veins of the same

[1] It is asserted on the authority of Schroeder, v. d. Kolk, that a passage of arteries over to veins occurs within the pia itself, so that all the blood brought by the arteries to the pia does not have to traverse brain substance. Thus they may act as a safety valve when the arteries are overcharged, for it is also asserted that these communications have been observed to dilate and contract. Any very prominent part, however, cannot be assigned to them.

tract: "Thus the chief branches end in a way in a communicating canal system [of the pia], a kind of reservoir, which is spread out in the shape of a tubular net over the whole surface of the brain." Duret, it is true, found but few arterial anastomoses in the pia; but Deeke seems to substantiate Heubner. The abundant communications between their finer branches, according to the latter (p. 195 *l. c.*), suffice, in case one of the arteries becomes impermeable, to supply its territory from the adjacent ones. As soon, however, as two main artery trunks on the same side become impermeable, the anastomoses no longer guarantee a sure compensation.

Unless the conditions were more favorable, a similar compensation in the venous circulation by means of the finest veins could not occur, for the circulation in them is impeded by two factors:

1. The far greater thinness of their walls and consequent tendency to collapse or rupture.

2. The absence of any considerable pressure in the venous current, a desideratum if a collateral circulation is to be established.

That they may stand upon a like footing with the arteries, they must have larger communications in sufficient number, and this is, in fact, the case. Not only the abundance of large anastomoses, but also the greater number of venous trunks in comparison with arterial, serve the same end.

The vessel, called by many authors vena anastomotica magna,[1] which acts as collecting vein, and also forms a com-

[1] Trolard has attempted to give this vessel an altogether unwarranted significance. At the same place, however, he has something to say of interest here: "Au moment ou elle [*i. e.*, la grande veine anastomotique, corresponding to what in this work is called vena cerebri media] quitte la scissure de sylvius pour adherer à l'aile du sphenoid, elle reçoit une branche qui vient de la base du cerveau, et dont le volume et la longueur sont tres variables. J'ai vu cette branche aller s'anastomoser avec une céré-

munication between the superior veins and those of the base, is, as I have found, only one amongst several of nearly or quite equal size, which just as well deserve to be called anastomosing veins. A fresh brain is most suitable for demonstrating these anastomoses, and for injecting material Pansch's surpasses even Berlin blue. The results will be more intelligible by describing a special case; this was very similar to another injection where Berlin blue solution was employed.

An adult brain, with usual relations, was carefully taken out and laid on the left side. A canula was then bound in a peripheral direction into one of the large veins near the sinus longitudinalis and Pansch's material injected. The vein immediately filled up, side branches appeared, and soon the material was running from a vein at the lower end of the fossa sylvii (v. cerebri media).

This was immediately stopped with a small clamp, and the injection continued. It soon began to flow from the vena occipitalis lateralis between which and the point of injection, numerous communications were evident. The colored mass could be seen to appear in several scattered veins, emerging from sulci, oft in fact in a remote vein sooner than in intermediary ones, until at length nearly all the veins of one side were filled, not only those quite adjacent, but many occipital and frontal vessels. It even passed back through these veins into the sinus longitudinalis.

The larger and more abundant communications center towards the middle of the side of hemisphere. In reality,

belleuse, et former un cercle veineux inclus dans l'hexagone artériel. C'est elle qui fournit les veines perforantes et une petite veinule au plexus choroide."

Rosenthal's description of these parts was evidently unknown to him. This statement would correspond to a case where the vena basilaris terminates near the flocculus, and anteriorly, perhaps, had an extra large communication with the vena cerebri media. This corroborates our description of these veins.

if one wishes to look at it so, all the external (here external is not used as synonymous with superficial, which would include those of the base and the great longitudinal fissure) veins of the brain arise or radiate from the upper, more horizontal part of the fossa sylvii; whereby it should always be remembered that some of the posterior ones soon turn upwards and forwards.

A few of these anastomoses are noticeably large, corresponding to the size of the vessels connected.

1. One upwards and forwards (superior anterior).

2. One upwards and backwards (superior posterior).

When one vein here was more developed, it has heretofore been considered a continuation of the following (No. 3), and the two together have been called v. anasotmotica magna.

3. One downwards and forwards (inferior anterior).

This one is with the v. cerebri media.

4. One downwards and backwards (inferior posterior).

This last is of course with the v. occipitalis lateralis.

There are often also very respectable anastomoses between the vena cerebri media, and vena occipitalis lateralis directly across the temporal lobe.

Communications likewise exist between the branches of the venæ superiores, running to the pia within the great longitudinal fissure and the ascending venæ corporis callosi externæ anteriores and posteriores.

Of importance were the results in another injection. It was proceeded with in the following way:

The skull-cap was removed without otherwise injuring the dura than intentionally making a small opening into the torcular Herophili. A large canula was tied into the sinus rectus by running a threaded aneurysm-needle around it through dura and brain-substance. The whole was then inverted and held free in the air that the basal and ventricular

vessels might be completely freed from pressure. It was then injected with considerable force. The material soon began to flow from the vessels at the neck, from the jugular on one side and probably the vertebral on the other. This was readily seen, since the head had been previously removed from the body.

It was thus pretty conclusively demonstrated that Galen's does not form an isolated system of veins. On removing the brain from the rest of the skull the proof became positive.

Of the veins on the inferior surface of the anterior lobe, a few were found injected even to the sinus longitudinalis; likewise several in the fossa sylvii. The venæ occiptales internæ had conducted the material over into several branches of the venæ occipitales externæ (s. laterales).

In the longitudinal fissure, twigs from the venæ callosi, etc., were injected as far as the convexity, and one inner superior (see above p. 13, about inner and outer branches of superior veins) vein had carried some of the material over into a vein on the convexity.

But the cerebellar veins were most strongly distended of any on the surface, and these had doubtless for the most part produced the outflow from the cervical vessels while injecting.[1]

From all this it is justifiable to assert that "*Galen's system of veins is not separate* (*isolated*) *from the other cerebral veins.*"

And yet too many conclusions must not be drawn from that. It should be remembered that all the anastomosing branches of this vein, as given above, were surface vessels—viz.: vena cerebelli superior, v. occipitalis interna, vena basilaris, vena callosi posterior externa. The rest forms the

B. Class of internal veins.

To these naturally belong the branches of the vena cornu inferioris and the rami perforantes, both usually running to

[1] The ventricular veins were very fully injected.

the basilaris. Only through the substantia perforata of the base, do larger venous branches pass directly from the cerebral substance to the outside. All other veinlets emerging at the surface, not only on the crest of the convolutions but at the bottom of the sulci, are scarcely or but just perceptible to the naked eye.

The internal veins in the strict sense, as far as their larger trunks extend, lie in the tela and plexus choroidea, processes of the pia mater. The veinlets contained therein evidently communicate with one another, like those in the external pia. But on following these internal veins farther in their ramifications, it transpires that beyond the tela and plexus, anastomoses are nowhere to be found. These medullary branches, before they pass over to the tela and plexus, usually run for some distance imbedded in the ventricular wall, just beneath the ependyma.

It may be well to compare the deportment of the arteries with that of the veins in this regard. According to the account given by Heubner, the arterial branches passing into the brain-substance are :

1. Very small ones, under 1 mm. in thickness, from the arterial net (see above p. 42) of the pia to the cortex cerebri.

2. Somewhat larger ones of the same origin, to the medullaris.

3. The rami perforantes, which arise directly from large arteries and enter through the white substance of the base.

For the last he proved that they enter into no anastomoses, from which it does not by any means follow that the other two classes do differently.

The results of Duret's investigations, as reported in the annuals for 1874, were similar. Deeke's description of the distribution of the finer arteries (*Am. Jrnl. of Insanity*, Apr., 1879) seems to bear out the idea that they form no anastomoses within the brain-substance. Charcot (*Localization in Diseases of the Brain ;* Transl. by E. P. Fowler, 1878), who bases his statements chiefly on the works of Duret and Heubner, claims that the cortical arterioles communicate only in their finest capil ary distribution. This is what constitutes a terminal artery of Cohnheim. Adamkiewicz (Lond. Med. Cong. *Trans.*, vol. i., p. 155), it is true, says that the finer arterial branches in the substance of the spinal cord anastomose freely—which certainly does not furnish an expected analogy.

For the brain veins the same holds true as for the brain

arteries. *Nowhere within the brain substance have I ever succeeded in finding a venous anastomosis.*

The two classes of brain veins given on p. 41 might perhaps be more closely limited, and named as follows:

A. Venæ superficiales cerebri (including only veins in the pia).

B. Venæ substantiæ cerebri.

Weber once described communications, larger than capillaries, as existing between brain veins and brain arteries.

DISTRIBUTION OF VEINS TO THE GRAY MATTER.

The gray matter of the brain and spinal cord is known to be very vascular. Accordingly a large share of the veins arise in those parts of these organs where the gray matter is accumulated. The network of small veins on the surface is largely to take up the blood from the gray cortical layer directly beneath. While the internal veins form no such net, and many of them pass much farther into the cerebral mass, still they also come for the most part from the corpus striatum and structures that are principally made up of gray matter.

ATTEMPT AT A DIVISION INTO EFFERENT DISTRICTS.

It hardly need be mentioned that such a division can be at best but approximate.

We must recur to the former division into—

A. Cortical layer and pia (venæ externæ).

B. Central ganglia and medullaris (venæ internæ).

A. The largest superficial tract belongs to the superior veins. It comprises the veins above an imaginary horizontal plane passing through the upper part of the fossa sylvii.

On the opposite but adjacent surfaces of the longitudinal fissure, those above the fissura calloso-marginalis go to the superior veins, the branches below go to the vv. callosi externæ, anteriores et posteriores.

Below the above-mentioned horizontal plane the posterior part (externally) as far as the middle of the temporal lobe, corresponds to the venæ occipitales laterales. Thence to the middle of the frontal lobe, it belongs to the vena cerebri media and vena fossæ sylvii, and everything farther forward, to the front superior veins.

On the base the greater part of the inferior surface of the frontal lobe, the genu corporis callosi, etc., are to be reckoned to the venæ basilares anteriores and all that region where the cranial nerves take their exit to the vena basilaris.

On the inferior surface of the occipital lobe the outer ones (external to the fissura collateralis) pass to the vena occipitalis externa (lateralis), the inner ones to the vena occipitalis interna.

B. Central ganglia and medullaris. Only the principal vessels are mentioned.

1.) The part above the plane of the lateral ventricles.

Anterior third. { Venæ medullares superiores.
Rami anteriores of vena lateralis ventriculi.

Middle third. { Ascending branches of vena lateralis ventriculi.
Venæ medullares superiores.

Posterior third. { Vena cornu posterioris.
Occasionally also vena cornu inferioris.

2.) The part below the said ventricular plane.

Anterior third. { Venæ perforantes anteriores.
Venæ cornu anterioris.

Middle third. { Vena lateralis ventriculi.
Vena cornu inferioris.
Rami thalami optici.

Posterior third. { About the same as in the posterior third above.

ANGLES MADE BY THE VEINS AS THEY DISCHARGE INTO THE SINUSES.

Of special importance to the circulation in the brain is the manner in which the cerebral veins empty into the sinuses. In general it can be characterized as an acute angle against the current, to which there are certainly some exceptions. It is very striking that the dural veins make an entirely different angle in emptying into the sinus from the superior cerebral veins directly beneath ; indeed, they empty in the opposite direction. The dura veins take a comparatively direct course to the sinus, or seem to be radiating out from the point of entrance of the middle meningeal artery towards the sinus longitudinalis. The superior cerebral veins at their termination, on the other hand, show a tendency to radiate from a point a little anterior to the middle of the long sinus.

As to the superiores. Attention has already been called to the more posterior ones taking a course more and more unfavorable to their free discharge. The most anterior of the superior veins make an angle of 90° or less with the direction of the stream. The posterior ones, on the contrary, describe first a curve forwards of about 90°, and then enter the sinus quite against the current direction which their contents are to acquire—*i. e.*, practically at an angle of 180°.

For the vena Galeni the conditions are similar, or, if anything, more unfavorable. *The sinus rectus bears the same relation to the vena Galeni that a tangent does to its circle.*

The blood from the interior of the brain must, therefore, flow down from the ventricle under the splenium corporis callosi (that from the rami perforantes may ascend with the basilaris), thence it passes around the splenium upwards and finally forwards, thus changing the direction of its current 180°. At the point of discharge into the sinus the

stream doubles on itself, or makes 180° more change of direction. This latter is identical with the discharge of the more posterior superior veins, except that these latter have in addition to meet a current coming against them. All in all, the conditions of discharge for the vena Galeni and for the most posterior superior veins are so equally unfavorable as to be very striking.

The blood takes its farther course downwards to the torcular Herophili, where it makes a right angle outwards, as does also the stream from the sinus longitudinalis.[1] Further on, at the so-called flexura sigmoidea, just above the foramen jugulare, they each describe again a right angle, this time downwards.

The arrangement of the veins at the base of the brain differs somewhat in this respect from those above. The venæ occipitales laterales run either straight or at the most but a little backwards to the sinus transversus, and not until they begin to perforate the sinus wall do they take a course more sharply against the current within the sinus.

Trolard (*l. c.*, pp. 257–8) describes this as follows: "The lateral and inferior [meaning simply the inferior branches of the lateral] occipital veins do not discharge directly into the lateral sinus. They unite near the external part of the horizontal portion of the sinus to form in the dura mater a

[1] Rüdinger (*l. c.*) emphasizes the fact, long known, that the blood from the sinus rectus usually passes on through one—oftener the left—sinus transversus, while that from the longitudinal sinus goes through the other, usually the right, which is in that case the larger of the two. He has a series of illustrations showing this relation, and states it held for seventy per cent or more of the cases he examined. He represents these two sinuses either as remaining quite separate at the torcular Herophili (confluens sinuum), or, if not, he speaks of a valvular arrangement whereby the two streams are kept practically apart. In this way a regurgitation of the blood from the upper into the lower sinus, or any special interference of the one current with the other, would be avoided, although he draws no such conclusion. Knott (*l. c.*) found that in twenty-six out of his forty-four cases the sinus rectus turned into the left lateral sinus, in six cases into the right lateral, and in the remaining twelve cases mæsially. Knott also claims that in a majority of cases the right lateral is the longer of the two. H. Meyer claims not only that the right lateral sinus and right internal jugular vein are, as is well known, larger, but that, owing also to the more vertical course of the right innominate vein, the blood flows through it in a quicker stream than through the left one. This would seem to give the surface of the brain a freer discharge than the central portions.

single vessel, which is directed from without inward. The blood flows then in this direction ; but by little orifices commonly existing in the sinus walls a part flows from within outwards. In other cases the veins on uniting form an ampulla-like cavity, from which two ducts usually emanate, the one of which is directed from without inwards, the other from within outwards. He has seen cerebellar veins empty into these cavities on the inferior surface of the falx cerebelli." The dilation spoken of may arise from the tendency to stasis at this point. It has however seemed sometimes to me to be but an artificial product, caused either by the rupture of the vein or the independent injection of a parasinoidal space surrounding the vein at this point.

For the other basal veins the conditions are likewise complicated. The sinus petrosus superior empties into the sinus transversus directly against the stream, and the flow from the former must be still further hindered from the transversus at this point making a curve downwards, whereby there would presumably be a greater tendency for its blood to wall against that in the petrosus. The vena cerebri media terminates in the middle of the sinus petrosus superior or in the sinus cavernosus. In the cases examined upon this point it seemed oftener to empty into the cavernous sinus. This latter sinus passes backwards principally, according to Luschka and Knott, to the superior petrous. The discharge from the lateral surface of the hemispheres would therefore be in any case about equally difficult, whether by the superior veins to the longitudinal sinus, or by the v. cerebri media to one of the basal sinuses, the superior petrous. The veins of the tympanic cavity are said to pass in part through the fissura petroso-squamosa to the veins of the dura mater, and by means of these to the superior petrous and the transverse sinuses. The vein contained in the aqueductus vestibuli, made up of branches from the semicircular canals, is described as passing either directly to the superior petrosal sinus, or indirectly by means of a middle meningeal vein. Knott found this sinus wanting in three cases, two of the right side and one of the left.

The sinus petrosus inferior presents a very different modus. It does not empty into the sinus transversus, but passes beside it, as vena petrosa inferior, through the foramen jugulare, and not until outside the cranium does it empty into the jugular vein.[1]

This I have corroborated on several skulls, both sides, only it should be noted that the two do occasionally unite while still within the canalis jugularis. This manner of termination is exceedingly favorable to the discharge from this sinus, and contrasts very markedly with that of the adjacent superior petrosal sinus.

Knott examined the bases of eleven skulls to determine the plane of termination of this sinus or vein. In eight out of the twenty-two, it was as nearly as possible at the level of the lower margin of the jugular foramen; in nine a little above, and in the remaining five a little below. In two it was about three-eights of an inch below the base. In the nine in the foramen it was at the junction of the middle and inferior thirds. It follows, therefore, that occlusion of the sinus transversus, even including its flexura sigmoidea, if it stops there, will in no wise interfere with the discharge through this sinus.

The inferior sinus, as given by Henle, takes up a branch from the venus flexus surrounding the hypoglossal nerve at its exit from the skull. This plexus coming from the occipital sinus, sends two veins downwards in the canalis hypoglossi, which end, the one in the vertebral plexus of veins, the other in the said inferior petrosal vein. This somewhat variable plexus (about the hypoglossus) draws its blood from much the same region as the inferior petrosal sinus (medulla oblongata, pons Varolii, adjacent parts of cerebellum, etc.), and has likewise a similarly favorable discharge.

The plexus basilaris (Cruveilhier, Virchow) sends some of its branches on either side, as stated by Knott and by Henle,

[1] Trolard, whose article appeared in 1870, claimed to have discovered this as a new fact. It is, however, very accurately described by Henle in his edition of 1867, also by Luschka in his Anatomy of the Head, 1867, and was doubtless known long before that.

to the sinus petrosus inferior, some to the posterior end of the cavernous sinus, while others pass downwards and communicate with the anterior spinal veins. These spaces (plexus) are known to be chiefly developed in the senile subject.

It is stated by Schwartze (in Kleb's *Handbuch*) that the venæ auditivæ internæ, which lie with the artery of the same name and the acoustic nerve in the porus acusticus, empty into the lower end either of the inferior petrosal or of the transverse sinus, which agrees with Hyrtl's description. But Urbantschitsch (*Ohrenheilkunde*, 1880) says they pass to the superior petrous sinus.

The comparatively insignificant ear veins have been referred to simply to show the sources of the sinuses in connection with the question of discharge.

We may cite gravity as an important factor in a mechanical explanation of these relations. In man, who walks upright, these impediments to the venous flow are much more marked than in animals (see pp. 55 and 56) carrying their heads horizontally. In them the angles in the venous current are never so acute as in man.

Heubner, on the other hand, notes the unequally favorable conditions for the arterial blood supply to different parts of the brain. This would necessitate, rather than a purely physical, a physiological explanation—*i. e.*, one depending on different functions or degrees of activity of the various parts.

Deeke, already quoted, concludes that in consequence of the arterial ramifications, the blood-pressure must be higher in the white than in the gray substance, but that the gray is correspondingly more protected from circulatory changes.

A. Eckert (*Wratsch*, abstract in *Centbl. f. d. Med. Wiss.*, 1882, p. 730), measuring with Basch's sphygmomanometer, on those just approaching puberty, found the blood-pressure in the left temporal artery from 1-10 mm. higher than in the right. This she believed due to the left carotid coming so often directly from the arcus aortæ, while the right carotid usually arises from the anonyma.

Carter (*Chicago Med. Jrnl. and Exm.*, Oct., 1883) gives several authorities and facts—not entirely unquestionable in their bearing—to show that the velocity of the blood-current in the left carotid is greater than in the right, and that more blood passes to the left hemisphere than to the right. He also uses this to explain the greater frequency of hæmorrhage into the left side of the brain.

These various facts and opinions, touching both the local venous and arterial circulation speak pretty conclusively for an unequal blood-pressure in like-calibered vessels of different parts of the brain; for, those parts having a relatively unfavorable venous discharge do not correspond, or only in part, to those having a relatively favorable arterial supply.

DEVELOPMENT.

There remain to be noted some embryological resp. comparative anatomical matters relating to the present subject. Let us first consider the superior veins. It is noticeable that there is a regular increase or variation in certain relations from the front backwards.

1. The angle made by the entering vein-current with the sinus-current increases.

2. The mouth of the vein moves around from above to the bottom of the sinus.

3. The sinus grows larger.

4. The breadth of the falx cerebri also increases.

No. 3 depends simply on the veins taken up along its course.

If one bears in mind that the brain in its growth doubles, so to speak, over backward and elongates somewhat, it is easy to see that, either from this or from an imaginable retardation in the growth of the falx cerebri—for which we have analogies—the brain would carry the pia with its veins backwards, the posterior ones a considerable distance, the anterior ones little or none at all.[1] Krause (*Virch. Arch.*, 1881,

[1] This can be prettily illustrated with a column of soft potter's clay. A stout cord runs straight along one side from end to end, representing the

p. 227) also claims this in explaining a peculiarity of a vein, of most importance in the fœtus, which he describes as lying in the sulcus meningeus. The actual proof of this must of course come from the comparison of embryonic and perhaps animal brains with adult human forms. The appearance on one small fœtal brain seemed to substantiate this—*i. e.*, the posterior veins did not stand so oblique to the sinus as in the brains of adults.

Only further investigation, however, can determine this point satisfactorily. The difficulty of getting and still more of properly examining young fœtal brains makes this something of a task. The deportment of these veins in animals speaks in favor of this theory that the above-named relations arise in the development and are not originally so formed, as we find them in grown persons. In sheep, calves and rabbits, which alone were examined, the front superior cerebral veins came from parts somewhat farther forward than their respective points of discharge, while the posterior ones came from tracts somewhat back of their termination, yet in the latter case far less so than in man.

This matter of the participation of development is much surer with regard to the vena Galeni. This vessel lies directly against the splenium corporis callosi. The latter is a part that is known to develop relatively late. In this way the vena Galeni, which at first was more nearly a straight continuation of the sinus rectus, is pressed more and more downwards and backwards by the growing sple-

sinus longitudinalis, small cross-strings firmly fastened to the large one at equal distances, a little pressed into the clay, but with their ends free, represent the venæ superiores. If now we fix one end of the column and cord, and then bend the other end of the column in a direction away from the cord, the latter will be seen to no longer reach the whole length of the now convex side; while, of the cross strings, the first are about as before, rectangular to the sinus, those farther back have been so pulled forwards and drawn down that they can be followed some distance beside the main cord before they pass out around the column. This corresponds closely to what seems to have occurred in man.

nium, until it at length has the peculiar course we have seen in the adult. The comparative examination of developed with fœtal brains bears this out. It was indicated a little in the case of a new-born child, but was specially evident in a 150 mm. long fœtus. The younger the fœtus the nearer to a straight vessel does the vena Galeni approach. This point cannot be profitably studied on animals, since in them the dura-processes are much less developed, and the sinus rectus, at least in sheep, rabbits and calves, is wanting. With these the vena magna Galeni leaves the floor of the ventricle between the thalami optici and corpora quadrigemina, and passes as a single trunk up and somewhat backwards to the sinus longitudinalis, with which it makes a right angle.

This vein in man has transferred its route farther back and down, and forms then the sinus rectus before reaching the long sinus. An apparently intermediary form was found in one young fœtus, where a communication of considerable size existed between the back part of the rectus and the long sinus a little before the torcular Herophili. A trace of this, or what appeared to be, I have also seen in adults, and perhaps the communication from the anterior end of the sinus rectus to the long sinus above, given by certain authors (Trolard, Heitzmann, etc.), is to be interpreted as a relic of what in animals is the rule

Knott also relates that in one of his cases the inferior longitudinal sinus, instead of passing to the sinus rectus, turned upwards between the layers of the falx and terminated in the superior longitudinal, 1¼ inches above the level of the internal occipital protuberance. In another case the straight sinus was completely absent. Galen's vein and the inferior longitudinal sinus met at the anterior edge of the tentorinum, as in the normal arrangement, but the fusion was only for a length of about ¾ inch. From this point three veins passed backwards—one between the layers of the falx cerebri upwards to join the superior longitudinal sinus an inch above the torcular, while the other two ran between the layers of the tentorium on the left side of the attachment of the falx. One opened into the left lateral sinus, half an inch beyond the margin of the falx; the termination of the other was an inch further from the middle line.

The reason for this transfer of position in man is easy to see. In him the dura sends strong processes (falx, etc.) into the cranial cavity for the support of his relatively much larger brain. If now the vena Galeni had remained as in animals, then either the falx cerebri would have to be too lax to act as a support, or its two component sheets would compress the soft vein. In the space, however, where the three tightly stretched membranes—falx cerebri and the two wings of the tentorium cerebelli—meet, this is no longer possible.

The vena Galeni relatively to the superior cerebral veins appears in the fœtus to be much larger than in the adult. Luschka (*l. c.*, p. 234) writes: "One may, therefore, assume with J. Kollmann (*Entwickelung d. Adergeflechte*, 1861) that the plexuses of young embryos, dilated with blood and quite filling the ventricles, are of decided importance for the rapid growth of the primarily anæmic nerve substance." The diploë of young animals is said to be very vascular (Schüller, *Berl. klin. Woch.*, 1874, No. 25). Compare also, in this connection, p. 18–19 above, concerning the abundance of dura veins in the fœtus.

The emptying of the vena basilaris at the base of the brain, which in man occurs in only a part of the cases, finds its counterpart in the animal. Here, after taking up its branches, it courses backwards beside the crura cerebri in a fold of the dura mater as a kind of sinus, and receives one large accessory, apparently the vena occipitalis. On continuing its course between cerebellum and occipital lobe, it reaches the analogon of the sinus transversus and leaves the cranial cavity.

PAIRED AND DOUBLE VEINS—VEINS ACCOMPANYING ARTERIES:

By paired veins are meant such as occur on each side, *i. e.*, symmetrically; by double veins, such as run some distance side by side.

1. The posterior vv. superiores cerebri are paired, and each shows a tendency to be double.

2. The vena cerebri media is often double.

3. The venæ intimæ cerebri, although lying side by side, are paired, and not strictly double.

4. The venæ meningea mediæ are also double.

Taking the two sides together, nearly all the cerebral veins occur symmetrically, although some of the ventricular and anterior superior veins may form exceptions.

Between the double vv. superiores no artery was to be seen. Langer, it is true, states that these veins are accompanied by minute arterial branches, but his examinations were limited to very young brains.

Even the veins passing through the parietal foramina seem to have an occasional arterial counterpart. Knott states that a ramus parietalis from the occipital artery accompanies the parietal emissary. Hyrtl, however (*Anat*, p. 171), apparently quoting from Wrany, says that where these foramina are distant from the sagittal suture, and perforate the skull-cap in a posterior and central direction, they contain arterial branches. The vein is then wanting or passes through an azygous opening in the parietal suture.

The venæ int. cerebri have no accompanying arteries. The v. cerebri media is often double, and corresponding to it we have the arteria fossæ sylvii. It has been said that the veins of the base accompany the diverging arteries, yet this can hardly be considered correct, certainly but in the most general way. Perhaps something of the kind might be made out as follows:

Corresponding Arteries and Veins of the Base.

Art. fossæ sylvii = vena cerebri media.

Art. cerebri anterior = vena callosi anterior externa.

Art. choroidea = vena cornu inferioris.

Rami perforantes = arterial and venous.

Art. meningea media = vv. meningea mediæ.

VENOUS PASSAGES LEADING OUT OF THE SKULL.

Although a systematic description of the dural sinuses has not been attempted, it may be well, from their importance to the local circulation, to tabulate the numerous venous connections between intra and extra cranial vessels somewhat as, though more fully than has been done by Henle in his "Anatomy." These may all act as efferent canals, although the ophthalmic veins are usually afferent, and certain of the others may, perhaps, conduct blood either way, according to circumstances.

1. Sinus transversus (S. sigmoideus), leading to the internal jugular vein.

2. Vena petrosa inferior, leading to the same jugular (s. above, p. 52).

3. Emissarium mastoideum, of most importance in fœtal life. This arises internally from the transverse sinus, and empties usually into the vena occipitalis (extracranial); sometimes, however, into the posterior auricular, or even directly into the external jugular vein (Luschka).

Sixteen skulls were examined by Green (*Am. Jr. of Otology*, vol. iii.) to determine the situation of this opening. One of the skulls had no such emissary, and a second had one only on one side. It was always just behind the posterior limit of the mastoid process. Its diameter measured 5 mm. in one, 4 mm. in four, 3 mm. in ten, 2 mm. in ten, and 0.5 mm. in four. The external opening was opposite the meatus, at about the middle of the perpendicular height of the mastoid in twenty, above this in two, below in six, and directly upon the base of the skull in one.

4. Emissarium condyloideum. Sometimes a vein passes out from the lateral sinus through the posterior condyloid foramen (Gray), or oftener from the occipital sinus through the same foramen to the vertebral veins (s. above, p. 39).

Under the same head may be included the veins noted on p. 52, passing through the canalis hypoglossi.

5. Emissarium occipitale, an azygous vessel (s. above, p. 19).

6 Emissarium parietale (s. above, pp. 19, 58).

7. A great number of minute veinlets connecting dural with diploë veins, some of the latter in turn connecting directly with external veins, the others indirectly. These filament-like vessels are in greatest number and largest size just above and a little lateral to the superior sinus, as was beautifully shown by a corrosion preparation.

8. Plexus canalis caroticus, from the cavernous sinus to the veins about the carotid below. Knott doubtless means this when he speaks of a vein or plexus of veins passing through the foramen lacerum medium and communicating with the cavernous sinous.

9. Vena ophthalmica (and v. ophthalmo-meningea).

10. Veins through the foramen ovale, or, according to Gray, foramen vesalii, connecting the cavernous sinus and meningeal veins with external veins (s. p. 40). Both foramen rotundum and spinosum are said also to occasionally transmit branches.

To the above may further be appended the following of rare occurrence in the adult subject:

11. Emissarium temporale, or sinus jugularius spurius, a relic of fœtal life (Luschka, Kirchner), which follows the petro-squamous suture and may perforate the temporal bone just behind the glenoid fossa, there to communicate with the temporal veins. Zuckerkandl found this twenty-two times in two hundred and eighty skulls.

12. Foramen cœcum, in fœtal life a communication between the longitudinal sinus and the veins of the frontal sinus, ethmoid bone and nose. I have never found this in an adult subject.

13. The very rare pathological sinus pericranii and likewise angiomas of the scalp are said to occasionally communicate, on the one hand with the external veins of the head, on the other through openings in the bone with the long sinus.

PHYSIOLOGICAL AND PATHOLOGICAL.

The foregoing part of this work, in connection with a variety of scattered data which it has brought together, leads to the brief discussion of certain points in the pathology and physiology of these veins. The subject of sinus thrombosis has been treated so often and fully elsewhere that it need not take up much space here; the like holds true of hæmorrhage from cerebral veins, and a variety of physiological matters have already received their share of attention.

The peculiar histology of these veins is one of the most important factors in their physiological action. But little is to be found on this head. The peculiarity itself consists in the absence of unstriated muscular fibres. One writer says there are none, another that they occur in certain of these veins, and still another (Krause), that they are only to be found in certain of the finer cerebral veins.

Although I have several times examined larger brain-veins, superiors and Galen's, for muscular elements, I have never succeeded in finding any.

There is, without doubt, a reason for their absence, and we may believe that they would be purposeless if they existed. The veins of the spinal cavity, the retina, corpora cavernosa and bones are likewise devoid of muscular elements. All of these are enclosed within either non-yielding or more or less elastic walls, where the ruling interior pressure is positive—in the cavernous structures, perhaps, only while in activity. There would thus be an antagonism between arteries and veins if the latter were also provided

with an independent contractility. In other parts of the body such an antagonism does not exist, and each class of vessels may expand or contract together or separately.

This want of muscular fibres and the thinness of their walls make the cerebral and retinal [1] veins more susceptible to general venous stasis than most others in the system. This would-be danger to the cerebral vessels is pretty well guarded against by their being little exposed to the effects of gravity and also by the non-yielding cranium whereby any increase of pressure in the veins tends to an increase of intracranial pressure, and thus furnishes the vein-walls with some support from without. We must also conclude, as will be indicated further on, that the pressure which ordinarily rules in these veins is very low.

These vessels form, then, a system of simple elastic tubes, with corresponding mechanical properties. Any active participation on their part in conditions of hyperæmia or anæmia is, as a necessary consequence of this, entirely out of the question, and there can be but two conditions with an increase of blood in these veins: *a*. one, where the discharge is in some way obstructed; *b*, the other from a deficient arterial supply. Neither of these forms is primary, but only a sequence. The first is accompanied by an increase of intravenous, and in some cases at least, intracranial pressure. It may, therefore, give rise to its own independent symptoms.

It is thought to be easy to produce experimentally that form of cerebral hyperæmia dependent on impeded venous discharge—viz., that it is only necessary to hold the head down. This produces most certainly a turgescence of the extracranial parts of the head, according to creditable authority (see Mosso's work) also some increase of the in-

[1] This similarity of structure and surroundings, together with the communications between them, makes the condition of the retinal veins so characteristic in certain cerebral troubles.

tracranial blood-quantity—which the expulsion of lymph would readily allow—and an increased vascular pressure within the skull; but it is questionable whether it retards the intracranial circulation in the least. Does not gravity accelerate the arterial current as much as it retards the venous? Without answering this unconditionally in the affirmative, it is nevertheless clear that the difference between the two effects, if any, would not suffice to produce serious symptoms from retardation of the current.

. Thus Moxon's citation of gymnasts, as bearing venous cerebral hyperæmia so well, loses its force.

The effects above noted of standing on the head are slighter in boys and young persons generally from their shorter height.

So long as the general health is good, these considerations are of little account, for, as Moxon urges, ligation of a jugular vein is usually borne without causing any trouble. There has also been one case at least, reported from Czerny's clinic, where both internal jugulars were successfully tied. In the second form of vein-distension the intracranial and the venous pressure are both diminished. The veins simply fill, as in senile conditions, ex vacuo. Here the venous engagement of itself can scarcely cause symptoms. This condition occurs when the arterial blood-supply is cut off. The arteries then force the blood out of themselves over into the weaker veins where it stagnates. Prince's case (*Surgical Memoirs of U. S. San. Comm.*, N. Y., 1870) illustrates an extreme form of this. A varix aneurysmaticus, caused by a wound of the left carotid and jugular, made ligature of the carotid necessary. *The veins of the brain and its membranes were found at the autopsy everywhere full of blood*, although there had been not only a reduced blood-supply to the left side of the brain, but a drain on the whole brain by the returning current through the circle of Willisi, down

the left internal carotid and by way of the varix into the jugular vein. This presented the unique condition of the cerebrum bled to death, while the whole remaining system, with the medulla oblongata and spinal cord, retained an adequate vascular supply. The arterial current flowing into the left jugular would rather assist than hinder the venous discharge.

The pallor of the face said (Buch), to accompany venous hyperæmia of the brain is most certainly but a part of the arterial anæmia, this latter leading to a passive distension of the cerebral veins.

An increased arterial supply so far resembles impeded venous discharge, that it also leads to a heightened intra-vascular and intra-cranial pressure. It might be imagined that this would also by compressing the veins lead to a retardation of the brain circulation, but according to the results obtained by v. Kries (below p. 68), this is questionable.

In cases of compression of brain space (depression of bone, tumor, exudation, extravasation), there is a corresponding anæmia with a decrease of blood-quantity, but an increased pressure intra-cranial, though according to Bergmann, not intra-venous.

The theory, that cerebro-spinal fluid was expelled from the cranial into the spinal cavity, at every systole and returned during the diastole, has within a couple of years been pretty completely exploded. It is now known that the rôle played by the said fluid in this matter is at most but a very subordinate one. Mosso's investigations on the venous cerebral circulation (*Kreislauf im mensch. Gehirn., etc.*, Leipsic, 1881), have been chiefly instrumental in accomplishing this. Previously it had been claimed that the venous blood left the skull in a steady, continuous

stream. He showed that at every systole a jet of blood was pushed out through the jugular opening.[1] He also made tracings through the mediation of a manometer, of pulsations in the superior sinus. By comparative measurements of the intra-cranial and intra-spinal pressures, he obtained further corroboration, and became convinced that while the intra-cranial blood-quantity, in an intact skull may vary considerably, the pulsatory displacements of the liquor cerebro-spinalis are very limited.

One of the most vigorous advocates of the old theory, that the cerebral blood-quantity changes from systole to diastole, is Hammond. It will be noticed however on examining his facts and arguments, that they are quite compatible with the present view, and go to show, not that there is a pulsatory change in the quantity of blood within the intact skull, but that the pressure varies.

Day says that in a young child with its open and elastic fontanelles, the amount of blood within the skull is subject to great variation. Such children however spend most of their time in a lying posture, and are also so much shorter than adults, that their brains have far less need of the protection from the effects of gravity, given by a non-yielding envelope.

It is natural, in considering this question, that attention should be directed to the foramen magnum, yet decisive observations—physiological or pathological—at this point are wanting.

[1] Previous to Mosso, there had not been wanting even recent writers who made little or no use of the oscillatory theory. Mosso, besides other historical notes, refers to Berthold (*Centbl. f. d. Med. Wiss.*, 1869), having likewise observed this intermittent pulse from the jugular in a dog, and Frank (*Gaz. hebd.*, July 8, 1881), claims that it had been observed and similarly explained long ago. Riegel (*Berlin. klin. Wochr.* 1881, No. 18), succeeded in always finding a diastolic pulsation in the jugulars of dogs and rabbits, and also of many healthy men. It was interpreted by R., in view of Mosso's work, as a negative pulsation. See also, Post, *Negative Pulse in Veins*, *N. Y. Med. Recd.*, February 17, 1883.

It is true Franck (*Le progrés med.*, Apr., 1882), who accepts the results of Mosso, and goes so far as to declare that the cerebro-spinal (cephalo-rachidian) fluid has no pulsatory oscillations between cranial and spinal cavities, has made an experiment to corroborate this. It consisted in applying an elastic ligature around the medulla oblongata and its meninges. He then trephined the cranium and caused the heart to cease beating, whereupon the cerebral veins were found distended with blood. This can scarcely be called a decisive experiment, although his conclusion that venous congestion accompanies arterial anæmia be true.

It is now generally acceded that the greater part of the cerebro-spinal fluid is to be found between pia mater and arachnoid, and that but a small quantity usually exists between arachnoid and dura mater. Both the spaces, especially, however, the former, must be occluded at the foramen magnum to prevent the supposed oscillatory motion of the fluid. In a discussion on hydrocephalus at the Lond. Path. Soc. (*Med. Tim. & Gazt.*, March 4, 1882), one gentleman at least said he had seen several cases where both these passages had been obliterated. From this it would appear that the patient can live, for a time at least, after this has happened. Whether these were all young subjects, whether the occlusion is ever found in adults, or is even necessarily fatal, I do not know.

Franck speaks also of the pumping action of the carotid where it passes through the cavernous sinus, at every systole forcing venous blood out, and during the diastole sucking other blood in. This seems very pretty, yet it is nothing more than a type of the whole circulatory action within the cranium—*i. e.*, the systolic accession of fluid forces so much venous blood out of the skull, while the veins fill again during the diastole. This compares with Braune's

demonstration of the pumping action of motion in the hip and elbow joints on the contents of veins and lymphatics in the inguinal and cubital regions.

A limited number of experiments may here be cited to further illustrate what has been said regarding the conditions of circulation in the brain veins.

Bergmann (*Würzburger Verhandlg.*, xiv., 1880) found that, "after injecting the posterior facial vein, which contains almost exclusively blood from the internal jugular [referring to animals, not man] compression of the other jugular or the aorta, or stoppage of the respiration, causes a rise of pressure in the cerebral veins." The increase from compression of the aorta, with at the same time some hindrance to the venous discharge, was perhaps a result of the arterial anæmia, the blood having passed over from them into and accumulated in the more yielding veins.[1]

He also found that on injecting solidifying material into the cranial cavity, thereby causing a compression of the capillaries [veins?], or on introducing foreign material (lycopodium) into the capillaries, the arterial pressure rose and the venous sank.

Naunym and Schreiber state that Cramer (*Dissert*, Dorpat, 1873) and Duret (*Etudes*, etc., Paris, 1878) have both found pressure on the brain to diminish the discharge of blood from the vena jugularis and the blood pressure in the same, and they demonstrate thus a retardation of the cerebral circulation by pressure on the brain. It should be added that

[1] It is difficult to understand why Mosso—and, I think, in some form, at least one other writer—puts forth the idea that the brain veins are devoid of valves in order to permit the regurgitation into them of blood from the sinuses, etc., when the arteries contract. Surely the contents of the arteries occupies the same space after it has been driven on into the veins or lymphatics. There are numerous conditions leading to retention and thus to accumulation of blood in the brain veins; but it is almost impossible to imagine any condition which could lead to a regurgitation into the brain veins, unless to a slight extent from those of the spinal canal. This, therefore, fails to give any evidence for or against the existence of valves in these vessels.

Cramer worked with Bergmann. N. and S. (*Arch. f. Exper. Patholg. and Pharmakolg.*, 1881, p. 59) continue by saying that "increased pressure in the subarachnoidal space will first affect those vessels in which the lowest pressure prevails—*i. e.*, the veins and then the capillaries. Now Kries has shown for the capillaries of the finger-tips, that on closing their efferent vessels the pressure in them rises until it equals that in the afferent arteries. In the brain the increased pressure in the capillaries would compensate until that used in compressing had reached the same height as that in the afferent arteries, and this would be, of course, a little below that in the carotid."

PRESSURE IN THE VEINS AND SINUSES.

Mosso measured directly the pressure in the longitudinal sinus. His method, said never before to have been tried,[1] was to bind a tube peripherally into the frontal portion of the said sinus. The sub-dural space was not opened, and the trephine opening was closed about the tube. On connecting this and the crural vein with the two branches of a differential manometer, he found the sinus pressure to be under narcosis 1–3 cm., out of narcosis 6 cm. higher than the crural pressure. He afterwards determined the absolute pressure at both points during and after narcosis. His conclusion that "the venous circulation within the cranium goes on under a higher pressure than in any other part of the body where it has as yet been measured," is, however, hardly warranted when we consider the peculiar surroundings of the brain veins. Only by connecting with a manometer, so as not to interfere with the free flow in the sinus, in addition to the other precautions, can it be hoped to de-

[1] Bergmann and Cramer had, however, employed a manometer in a vein at its exit from the skull.

termine the actual local venous pressure.[1] As an illustration of the increase of intravenous pressure in the human subject, on stopping the discharge through the long sinus, one has only to recollect the numerous cases of rupture of vein walls after sinus thrombosis. Huguenin even gives a case where thrombosis of a vein, just before its entering the sinus, led to a rupture of the vessel peripheral to the thrombus; but this belonged to a class of cases where he found extensive fatty degeneration of the vein walls, and does not prove that the slightly increased pressure would have ruptured a healthy vessel.

On the other hand, Archambault says (*Dict. Enc. d. Sc. Med.; Art. Meninges*, p. 566) that the flow from an opened longitudinal sinus is very slow. This is not strictly true, although the flow can be easily held back, and is such as to indicate a low pressure. For this reason hæmorrhage from an unwounded sinus is so rare. In caries of the mastoid process the transverse sinus may block, but rarely bleeds,[2] while quite a number of cases are known of bleeding from the much better protected carotid. The very resistant sinus walls certainly have a share in this immunity.

German writers often mention varicose dilation of cerebral veins as accompanying certain troubles, but Moxon (*Influence of Circulation on the Nerv. Syst.*, 1881) says that, amongst the several thousand examinations which he has made, he has never yet seen a case of this.

Again, it is clear from the anatomical relations that the blood pressure in the veins must be higher than in the sinus, and yet even in the veins it is not sufficient to require thick walled vessels. This alone is strong evidence that the usual venous pressure here is very low.

[1] In regard to this point Dr. Bartley, of Brooklyn, and myself, are making some experiments. If we succeed in arriving at positive results they will doubtless be made known.

[2] Recently a case of fatal hæmorrhage from the inferior petrous sinus has been published (Böke, *Arch. f. Ohrenheilk*, XX.).

There is, therefore, nothing in anatomy or pathology to bear out Mosso's idea of a high intravenous pressure in these parts.

Another questionable point in this connection has been settled within a few years. It was not previously known whether the pressure in the sinuses ever became negative. This can now be pretty safely answered in the affirmative. Genzmer in 1877–8, reported a case from Volkmann's clinic, where in attempting to remove a cancer of the dura mater, the longitudinal sinus was opened, and so much air was aspirated as to prove rapidly fatal.

This was probably at a distance upwards from the heart, a little farther than any similar occurrence as yet experienced in the opposite direction. Francois-Franck states, that the danger gone *of the surgeon* does not extend much beyond the hepatic portion of the vena cava inferior for the part below the thorax and Rose in Volkmann's *Sammlung*, (*Chirurgie*, No. 29, p. 748), says it has never been ascertained, whether penetrating wounds of the crural veins may, from entrance of air be immediately fatal. This was however practically determined by Warren's case (*Surg. cases*, etc., Boston, 1867, p. 529). In removing a tumor of the thigh he cut, the vena saphena as it pierces the fascia, whereupon a sucking sound was heard, as of air being pumped into a vein. This was stopped, and the patient recovered. Holmes in his surgery, tells of a case which proved fatal, probably from the entrance of air into a vein after amputation of the thigh. Still the spot where air entered the sinus, seems to be rather farther removed from the heart.

By letting the head hang down this danger from operating near the sinus would be minimal. A résumé of thirty-three fatal cases of entrance of air into veins while operating is given by Couty (*Etudé*, etc., Paris, 1875). He gives two cases of entrance of air into the occipital vein, and two into the facial. A case is now pending in a Connecticut court where it is believed that the final cause of death was the entrance of air into the anterior or middle temporal vein. Dr. Porter, of Bridgeport, who made the autopsy, has with great kindness placed the history of the case at my disposal.

The following brief abstract will here suffice, since he purposes publishing a full review of the subject when it is finally settled :

A woman æt. 35 years was struck across the forehead with part of a chair, making a clean incised, rather than contused wound, extending upwards and outwards, the internal angle about one inch from the median line, and the same distance above the supraorbital arch ; length of skin incision was about one and one-half inches. Profuse hæmorrhage followed the injury. Trismus set in five days later. Death on tenth day by gradual suspension of respiration after further convulsions. The wound had not healed. At the autopsy the bone was found partially denuded of periosteum. On removing the calvaria, as the saw passed through the inner table, a little pyramid of bloody froth bubbled up from a small opening about the squamous suture. External vessels of the brain much congested, the smaller ones filled with blood and bubbles of air. The inferior and superior cavæ contained a large amount of blood mixed with air. Walls of heart relaxed. Right auricle and ventricle filled with a frothy mass of blood and air—a spumous fluid. On opening the cavity there was an escape of bubbles of air. Left side of heart contained semifluid blood unmixed with air.

This case and those from Couty—if we accept them—show that the veins of the neck may transmit thoracic aspiration. In Porter's case the convulsions may have been the important factor in producing or transmitting the aspiration.

It may, however, be urged against Genzmer's case that the said sinus has often been punctured and even torn without this result. Besides, where the transverse sinus—a step nearer the thorax than the longitudinal—has been perforated, either by caries of the mastoid process or, as in the cases of Knapp, Schwartze and Benton,[1] during an operation, blood has flowed out, not air in. This is, however, only negative evidence, and of the less value since proven cases of free opening into this sinus are very rare—the above three may have been but punctures—and any bleeding would be imme-

[1] A case of probable opening of the transverse sinus during operation, but farther back than in the cases of Knapp and Schwartze, who were operating on the mastoid process, is given by Benton in his article on Trephining (*Proceed. Kings County Med. Soc.*, Jan. 1884, p. 260). All of these cases recovered, I believe, so that in neither of the three is there absolute proof that the sinus was opened.

diately seen, while the entrance of air, except in operated cases, might be overlooked.

The intravenous pressure is probably never much above the intracranial, and usually a little below that. During the diastole the pressure falls somewhat from what it is at the height of the systole, and anæmia, from whatever cause, reduces it still farther. The various circulatory relations must be greatly affected by the person's age. In advanced life there is a far greater tendency to negative pressure. It is well known that the nerve-mass decreases in elderly persons, as evidenced by the enlarged perivascular spaces, the widened cerebral veins, the increased size of some of the sinuses, and by the drawing in of cicatricial coverings when such exist. This diminution of contents, with the aid of gravity and perhaps of transmitted thoracic aspiration, may suffice to make the intracranial pressure very low, or even negative. From the nature of the growth Genzmer's was doubtless an elderly patient, although I have not the exact age. All that we can safely conclude, therefore, is that in senile persons a negative pressure may occur in the sinuses, without, however, asserting that this is communicated from the thorax.

This factor of a reduced pressure is not properly recognized amongst the causes of many cases of arterial apoplexy, the vessel-walls no longer receiving their accustomed support from extra-vascular pressure, and being perhaps further subjected to an occasional negative strain.

Francois-Franck has put forth a theory (*Gazt. hbd.*, June 17, 1881) that air can be introduced into the veins in consequence of cranial wounds which lay bare the osseous vein-canals, especially those of the occiput. He claims, as has often been done, that the action of atmospheric pressure upon the middle and superior portions of the jugular vein, does not allow the transmission of thoracic aspiration to the venous canals of the head. But in the vertebral veins he finds all the anatomical conditions necessary to its realization. He asserts further that experiments on animals demonstrate this—*e. g.*, if, after tying the internal and external jugular the animal exe-

cute sufficiently energetic inspiratory movements, air enters the opened diploë-veins. He does not, however, seem to specify distinctly that he had tied the jugulars on both sides. Again, where there was an occipital wound, on tying a syringe-canula into the superior end of a severed vertebral vein, he could aspirate air provided the venous canals of the occiput had not been stopped with wax. If, on the contrary, the jugulars be left intact and the vertebrals ligated, either no air is introduced on forced inspiration, the most usual case, or it is produced with much more difficulty. One must acknowledge the possibility of the vertebral veins acting as he thinks, though Franck's experiments, reasoning and conclusions are rather the opposite of convincing.

BEARING OF KNOWN PATHOLOGICAL FACTS ON THE QUESTION OF VEIN-ANASTOMOSES.

There are a number of recorded pathological observations which go to show that the internal cerebral veins, as explained above, enter into no anastomoses.

Many cases are known where tumors of the cerebellum, corpora quadrigemina, etc., pressing against the vena Galeni, have caused internal hydrocephalus. It is claimed that those pressing against the straight sinus may lead to this, but it is probable that these do it quite as much by compressing and displacing the vena Galeni and the venæ intimæ where they pass around the splenium corporis callosi. A slight pressure at this point would suffice to greatly interfere with or completely stop the flow in these veins, and this at a point far enough along on the portio curvata to preclude the external or anastomosing branches, which here join the intimæ, carrying off adequately the blood from the interior. The peculiar course and surroundings of the portio curvata, as described in the body of this work, expose it gravely to any such influences.

Schüppel (*v. Ziemmssen's Handbuch, Galle & Pfortader*, p. 324) gives the case of a youth of sixteen years, where, in addition to phlebitis hepatica adhæsiva, he found the *superior longitudinal and both transverse sinuses obliterated by a completely organized thrombus.* The patient, who had suf-

fered much from headache, died of a fresh sero-fibrinous pleurisy.

If the said sinuses were fully obliterated there could hardly have been any communication left, say between the straight and occipital sinuses, and the blood which usually discharges through the straight sinus must have found its way by the anastomoses described on p. 45. The possibility of such a compensation occurring after occlusion of the sinus rectus (or of the vena Galeni) must, therefore, be considered established.

On the other hand, occlusion of the said sinus or vein, together with the compensating vessels, or of the main trunk before it reaches these vessels, is, from the cases of which I have collected notes, always fatal, and pretty rapidly so, although its duration cannot, of course, be exactly determined. I have found three such cases in the American literature alone. Delafield (*Handbook of Post Mortem Examinations*, N. Y., 1872); Meigs (*Transact. of Phila. College of Physc.*, 1877), and Rotch (*Bost. Med. and Surg. Jrnl.*, Aug 23, 1883).

Then there are cases of tumors—usually originating in the choroid plexus—which cause symptoms by pressure on the venæ intimæ or its branches. Foerster (*Pathl. Anat.*, p. 797), mentions a tumor of the choroid plexus of the third ventricle, which caused exquisite capillary ectasies. A more frequent result from compression of these veins is ventricular dropsy. Such a case was reported by Stedman (Bost. Med. and Surg. Jrnl., Aug. 9, 1883), where there is also reference to a very similar one in an early number of *Virch. Archives*. In S.'s case there was a cystic tumor, size of filbert, upon the velum interpositum in the median line behind the fifth ventricle, in the region of the anterior commissure, thus evidently compressing the veins which unite near this point to form the vena intima. Equally confirmatory is Bristowe's

Case III. (*Brain*, July, 1883), where a tubercular mass about one and one-half inches in diameter occupied the third ventricle, involved somewhat both optic thalmi and led to much distension of the lateral ventricles with clear serum.

That the exudation into the ventricles in these cases is owing to the hindrance to the venous discharge caused by the growth, is shown by the fact that equally large tumors, when so situated as not to compress the veins, take their course without causing any special increase of the ventricular fluid.

All this speaks strongly for the absence of venous inosculations within the brain-substance, not only between internal and external veins, but between the internal veins themselves. From the few known cases and facts which are at all decisive, it is not advisable to draw too exact conclusions. But it would certainly seem true that—

1.) Closure of the sinus rectus or of the short trunk of the vena magna Galeni can be fairly compensated by means of the anastomoses (p. 45).

2.) If at the same time the discharge through the compensating vessels be interfered with, internal hydrocephalus may result.

3.) If this interference be very rapidly produced, or very great, the fluid may become more or less tinged with blood. This is more a proposition than a demonstration.

4.) If the main and also the compensating (*i. e.*, anastomosing) vessels be completely occluded, then softening of the corresponding brain-tract with or without ventricular hæmorrhage will result. Venous hæmorrhage into the ventricles would probably follow, unless the smaller and parietal vein-branches became occluded at the same time as or before the main trunk.

So far as present facts go, that part of the venæ intimæ described above as portio curvata is the one limited tract, the

occlusion of which cuts off every outlet for the collective ventricular veins, since they all unite in this portion, and this alone has important anastomoses with superficial veins.

The slit by which Galen's vein enters the sinus rectus is another weak point. Any displacement of the falx on the one hand, or of the vein on the other, may obstruct the venous discharge here. It would be interesting in cases of congenital internal hydrocephalus, to study the condition of this opening, for, as shown above, the ventricular veins and vena Galeni are in the fœtus relatively larger and fuller than in the adult, requiring of course a relatively larger slit in the sinus wall. It is, however, difficult to make a satisfactory examination of such affected parts, as I have found.

That a displacement of falx and tentorium is produced by internal hydrocephalus was shown by Humphrey (Lond. Pathl. Soc., May 5, 1881): "The distended lateral ventricles," he says, "dilate all parts of the cranial cavity except the base. The corpus collosum is carried upwards and the falciform process of the dura mater is lengthened, enlarged and carried also upward. This causes a drag upon the tentorium upward, which might be so great, as in a vertical section, to show the tentorium ascending perpendicularly from the torcular Herophili, to the point of entrance of the vena Galeni. Such was the condition in a specimen lately added to the pathological collection at Cambridge." Thus it is evident that at least secondarily the conditions of venous discharge must be greatly affected by internal hydrocephalus.

One reason why the internal or ventricular form of hydrocephalus, exclusive of congenital and that coincident with meningitis, is so much more frequent (Heincke in Pitha-Billroth) than the external form, is clearly the peculiar arrangement of the venous discharge from the ventricles and the few anastomoses of ventricular with superficial veins.

The former have but one regular exit—the v. magna Galeni —and this easily interfered with, while the superficial veins can discharge in various directions.

LIGATION OF THESE VESSELS.

Berard (v. Bruns, *Chirurgie*, I., p. 613) excised a portion of the longitudinal sinus and of the falx cerebri. The case proved rapidly fatal.

This sinus has, however, been successfully ligated. Küster (*Berliner Klin. Wochschr.*, Nov. 14, 1881), in extirpating a sarcoma of the frontal region, laid bare the said sinus, seized it with forceps, and, after tying, could sever it without loss of blood. The patient recovered from the operation, but died later from a relapse.

Parkes (*Ann. of Anat. and Surg.*, Sept., 1883) applied a lateral suture to a torn and bleeding longitudinal sinus. The hole was large enough to admit the end of the little finger, and was, from his description, a little back of a line joining the parietal eminences. He thinks the caliber of the sinus was reduced by the suture at least one third. Recovery.

Schellmann is said to have shown, by experiments on animals, that sinus-wounds may heal without obliteration of the sinus.

Pickman (*Lancet*, Nov. 20, 1880) has even ligated a vein in this vicinity with success. It was a case of comminuted fracture of the right parietal bone with exudation of blood between dura and skull. He says he found on trepanning, a dural vein which had furnished the blood. Possibly it may have been one of the superior veins; in any case, the patient recovered.

From the arrangement of the sinuses at the Torcular Herophili, it follows that a thrombus originating in the longitudinal sinus has a greater tendency to continue on into the right transverse sinus, and conversely. Of course, where the longitudinal turns to the left the opposite holds true. It turns to the right in something like two-thirds of all subjects (see above, Knott and Rüdinger).

The straight and the left transverse sinuses must have a similar mutual relation.

The internal veins and the straight sinus are, from their deeper position, much less liable to thrombosis than the superior veins and the longitudinal sinus. We have seen that thrombosis of the former must be considered more dangerous than of the latter. The above arrangement gives a considerable protection against a continuation into the inner veins of a thrombus forming in the longitudinal conductor.

In a former article (*l. c.*) I have called attention to the lacunæ laterales sinuum being so conditioned as to favor the formation of thrombus, and showed that such had been observed in them, both by others and by myself. A thrombus in these spaces would readily and naturally grow on into the sinus.

An endophlebitis luetica of the brain veins, like what has been observed on certain other veins, or like the end-arteritis of the same region, has never been observed (cf. Baumgarten, *Virch. Arch.* 1881, No. ii.), although Huber has described an endophlebitis deformans chronica from the brain of a syphilitic individual. Cretefaction and fatty degeneration may also overtake brain-veins.

Any cerebral vein may become filled with a thrombus, and this may be either primary or secondary. The superiors

seem most disposed to this, and next to them comes, perhaps, the vena cerebri media in whole or in part.

A case of thrombus in a vein, evidently the cerebri media with its branches, was given by Janeway at the N. Y. Acad. of Med., Apr., 1882 (*Med. Recd.*, June 5, 1882). A very similar case symptomatically as well as pathologically, was published by Raymond (*Gazt. hôpt.*), and still another by Abercrombie (Obs. XXVIII. of his work on the brain and spinal cord).

These cases, followed as they were by softening or degeneration of the corresponding brain-tract, show that when the outlet by means of the pia-veins becomes completely blocked in any region, the internal veins do not act as substitutes, and consequently, that the two do not anastomose.

By injecting purulent matter in an animal Blaschko (*Virch. Arch.*, Vol. 83) produced thrombi, which he called bacteria-emboli, in veins and capillaries especially in the corticalis of cerebrum and cerebellum. None were found in the arteries, which B. considers were protected by their rapid current.

Plugs in the cerebral veins are, says Nothnagel, identical with those in other veins of the body, as regards their transformations and relations to the vascular wall.

Sanders (*Am. Jrnl. Med. Sci.*, July, 1881) has collected the published cases of venous effusion directly into the ventricles. He seems to have found 17–18 pretty clear examples. This did not include the cases where the blood came from veins beyond the ventricle walls.